CANADIAN JOURNAL OF RESEARCH

VOLUME 21 DECEMBER, 1943 NUMBER 12

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OTTAWA, CANADA

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	Annual	*Single Copy*
A and B	$ 2.50	$ 0.50
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Canadian Journal of Research

Issued by THE NATIONAL RESEARCH COUNCIL OF CANADA

VOL. 21, SEC. C. DECEMBER, 1943 NUMBER 12

VARIETAL DIFFERENCES IN BARLEYS AND MALTS

XIII. WORT ATTENUATION, VISCOSITY, AND TURBIDITY, AND THEIR INTER-RELATIONS[1]

BY W. O. S. MEREDITH[2] AND H. R. SALLANS[3]

Abstract

Determinations of degree of attenuation, viscosity, turbidity at filtration, and turbidity after 24 hr. were made on the worts from 144 malts representing 24 barley varieties grown in 1938 at each of six widely scattered points in Canada.

Varietal and station differences are demonstrated in these wort qualities. *O.A.C.* 21, Mensury, and Olli, acceptable malting varieties, produce worts that are high in degree of attenuation, low in viscosity, and low in turbidity. Two other six-rowed varieties, Brandon 216 and Velvet, are similar to *O.A.C.* 21 in wort qualities. The remaining 14 six-rowed varieties are deficient in at least one wort quality. Among five two-rowed varieties, Hannchen being used as standard, Rex and Sanalta are similar to Hannchen in the three wort properties, and Charlottetown 80 and Victory are deficient in one or more.

Intervarietal relations between the wort properties were examined, and the following observations are made: degree of attenuation and viscosity are inversely related; viscosity is directly related to both initial and final turbidity, and partial correlation coefficients suggest that the material causing final turbidity is mainly responsible for these relations; initial and final turbidity are closely and directly related. No intravarietal relations were examined owing to the small number of stations represented.

From the brewer's viewpoint, the quality of a malt depends primarily on the amount and quality of the extract, i.e. wort, that it will yield. Comparative data on extract yield can be readily obtained in the laboratory, but determinations of quality present certain difficulties. Now that Canadian plant breeders are producing numerous new lines yielding adequate amounts of extract, it has become increasingly important to pay attention to quality factors. In this laboratory, wort quality has been defined largely in terms of nitrogen content and enzymatic properties (3), and it appeared that additional determinations would prove useful.

[1] *Manuscript received August 20, 1943.*

Contribution from the Malting Laboratory, Division of Plant Science, the University of Manitoba, Winnipeg, Man., with financial assistance from the National Research Council and the Dominion Department of Agriculture. Published as Paper No. 217 of the Associate Committee on Grain Research.

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Among the wort properties that are closely observed by brewers there are three that appeared to lend themselves to laboratory investigations. These are viscosity, turbidity, and degree of attenuation, which is a measure of the amount of fermentable material in wort. Though the actual amount of fermentable material extracted from a given malt may be controlled within certain limits by choice of mashing conditions, the amount of potentially fermentable material should be as high as possible in order that a brewing program may be flexible. Highly viscous worts, and the presence of haze in worts, are regarded as undesirable. As varietal differences in barleys and malts have been demonstrated for a number of other properties (4, and other papers cited therein) it was logical to expect varietal differences in these three wort properties also. Accordingly, it seemed desirable to examine a series of Canadian barley varieties with respect to fermentability, viscosity, and turbidity.

Materials

The investigation was carried out on a set of 24 varieties of barley, each of which was grown in 1938 at six experimental stations in Canada as part of agronomic trials known as the Uniform Variety Trials. The samples for malting were obtained by procedures previously described (2). The varieties and stations are listed below.

Varieties.—Six-rowed, rough awned, Manchurian type:—*O.A.C.* 21, Mensury, Olli, Peatland, Pontiac. Six-rowed, rough awned, Coast type:— Trebi. Six-rowed, smooth awned:— Alberta 8, Brandon 216, Byng, Newal, Nobarb, Ottawa E. 25, Plush, Prospect, Regal, Saskatchewan 264, Velvet, Wisconsin 38, York. Two-rowed, rough awned:— Charlottetown 80, Hannchen, Victory. Two-rowed, smooth awned:— Rex, Sanalta.

Stations.—Lacombe, Alta.; Brandon, Man.; Winnipeg, Man.; Ste. Anne de la Pocatiere, Que.; Fredericton, N.B.; Nappan, N.S.

Methods

Malting Methods

The samples were malted in duplicate in the equipment and by the methods previously described (20).

Analytical Methods

The barleys and malts were analysed, in the course of routine malting tests, for the commonly measured properties, and the results have been reported elsewhere (21). The duplicate subsamples of each malt were then bulked and the composite again split into two aliquots. One of these was used for other determinations, the results of which have yet to be published, and the second was retained in a sealed can until used for the wort quality studies.

Almost a year elapsed from the time that the samples were malted until the wort quality determinations were made, hence the data represent qualities of stable malts. Worts were prepared in the usual way (1), and aliquots were withdrawn for the various analyses. Duplicate determinations were made on one-third of the samples, and the standard errors of analysis were calculated

from the pairs of data thus obtained. The samples on which duplicate determinations were made were selected at random, after imposing the limitation that two samples of each variety and eight samples from each station should be chosen. Analyses were carried out in random order at a rate of six samples per day, on two days in each week.

Viscosity

Viscosity was determined at 20° C. by means of an Ostwald viscosimeter. Three trials were made on each wort sample. The average value was used for conversion into relative viscosity in the usual way using water as standard. The mean relative viscosity was 1.52, and the standard error of the mean of duplicate determinations was 0.01.

Initial Turbidity

Turbidity was determined on each wort immediately after filtration by means of a Zeiss Pulfrich Nephelometer. The results are reported in per cent of the standard aperture, using filters No. 4 and *L2*, and wedge illumination. (The formula for converting relative turbidity into absolute turbidity is as follows: *Absolute turbidity: = relative turbidity* $\times$ *0.0290* + *166.7.*) The standard error of the mean of duplicate determinations was 2.6%, and the mean initial turbidity was 37%.

Final Turbidity

The samples of wort used for the determination of initial turbidity were poured into test-tubes and the tubes were tightly stoppered. They were then placed in a water-bath maintained at 10° C. Turbidity measurements were repeated on the samples after 24 hr. The standard error of the mean of duplicate determinations was 18%, and the mean final turbidity was 162%.

Stability

The values for this determination were obtained by subtracting the values for initial turbidity from those for final turbidity, and subtracting these differences from 200. The final subtraction was made in order that higher stabilities would be indicated by an increase in numerical value. The standard error of the mean of duplicate determinations was 18, and the mean stability was 75.

Degree of Attenuation

One hundred and fifty ml. of wort was mixed to a smooth paste with 24 gm. of commercial bakers' yeast (supplied fresh each day) in a mash beaker. The beaker was then placed in a mash bath maintained at 20° C. and the contents were stirred constantly for 4.5 hr. The fermented wort was filtered overnight and the specific gravity was determined and corrected by means of a blank determination. This is the method described by Silbereisen (24), except that no yeast fat was used. Apparent degree of attenuation was calculated by the formula given by Pawlowski–Doemens (22). The mean apparent attenuation was 77.1%, and the standard error of the mean of duplicate determination was 0.6%.

Significance of Properties Measured

Among the wort properties examined, turbidity has received much more attention than either degree of attenuation or viscosity. This is probably because the latter are subject to more precise control during brewing than is turbidity. Several authors have reviewed studies on wort turbidity (13, 14, 15, 16) and agree that it is caused by material of high molecular weight, some of which is protein. Part of the non-protein material in the haze complex has been identified as tannin (6, 7, 8, 10, 11, 12, 15). Other materials reported as having been found in haze are pectin (6), silicic acid (10, 12), carbohydrates, pentosans, and possibly dextrins (12). It has been suggested (25) that measurements of turbidity, or of any other quality characteristic, made on laboratory worts do not provide a satisfactory basis for predicting the quality of the beers made from malts so tested. However, it should be possible to obtain useful comparative data if it is true that turbidity is caused by properties inherent in the barley and is controlled more by variety and season than by malting conditions (6, 9, 10). In this connection it should also be noted that Hartong (10) has suggested that the materials responsible for turbidity in wort are similar to those that cause turbidity in beer.

Degree of attenuation is actually a measure of the change in specific gravity of wort, when it is fermented with yeast, due to conversion of carbohydrates into alcohol. It thus represents the amount of low molecular weight products of starch degradation that are present in the wort since only simple sugars can be fermented by yeast. The determination of viscosity is simple and readily interpreted. It is an established fact that the viscosity of biological extracts is dependent on the molecular or colloidal size of the solute, and that viscosity increases with increase in this size. Wort viscosity is therefore a measure of the extent of degradation of starch and protein material and reflects the average size of the particles of wort solids. Turbidity measurements indicate the amount of haze forming material that is of colloidal dimensions and, since turbidity increases on standing, it is assumed that the change is due to aggregation of partially degraded material. Hence the value for stability, which is obtained from the difference between initial and final turbidities, is a measure of the material responsible for the increase in turbidity. All determinations have, therefore, factors in common. Degree of attenuation and viscosity are of direct interest to maltsters and brewers, and information on these is of value when examining the data for turbidity.

It must remain a moot point as to whether the differences in turbidity, attenuation, and viscosity that occur in laboratory worts will be reflected in commercial brewing. In all probability, small differences will not be so reflected, but the authors believe that large differences, such as those that occur between varieties of widely different types, must have some effect in the brewery. It appears that malting chemists may well take account of those differences in advising plant breeders with respect to the probable reaction of maltsters and brewers to the chemical characteristics of new varieties of barley.

Results and Discussions

Differences Between Varieties

The mean values, over six stations, for each variety for each determination are given in Table I, and necessary differences, calculated in the usual way from analyses of variance, are also listed. The range for each determination is considerable and varietal differences are demonstrated for each quality.

TABLE I

VARIETAL MEANS FOR WORT ATTENUATION, VISCOSITY, TURBIDITY, AND STABILITY

——	Attenuation, %	Viscosity	Initial turbidity, %	Final turbidity, %	Stability
1. *O.A.C.* 21	78.2	1.46	18	130	88
2. Mensury	77.4	1.48	18	134	84
3. Olli	79.4	1.44	19	120	99
4. Peatland	77.5	1.48	46	176	70
5. Pontiac	77.0	1.50	22	123	99
6. Trebi	77.0	1.57	40	163	77
7. Alberta 8	76.8	1.52	27	164	63
8. Brandon 216	78.7	1.45	28	142	86
9. Byng	75.8	1.64	47	196	51
10. Newal	77.5	1.54	27	154	73
11. Nobarb	78.0	1.54	29	169	60
12. Ottawa E. 25	74.6	1.67	50	218	32
13. Plush	77.6	1.57	47	188	59
14. Prospect	76.1	1.56	37	208	29
15. Regal	75.1	1.49	38	116	122
16. Saskatchewan 264	75.4	1.48	27	121	106
17. Velvet	77.8	1.48	32	148	84
18. Wisconsin 38	75.7	1.59	73	238	34
19. York	77.6	1.58	102	262	40
20. Charlottetown 80	77.9	1.49	61	218	43
21. Hannchen	77.2	1.50	18	101	117
22. Victory	76.0	1.56	21	137	84
23. Rex	77.7	1.46	18	119	99
24. Sanalta	78.4	1.51	39	140	99
Mean over all varieties	77.1	1.52	37	162	75
Necessary difference, 5% level	1.7	0.06	24	64	59

It is important to observe that worts from *O.A.C.* 21 are high in degree of attenuation and low in viscosity and turbidity. These characteristics are desirable from the brewer's viewpoint, and it is not surprising to find that they are exhibited by *O.A.C.* 21, which is considered the best barley grown in Canada for the production of brewer's malt.

Mensury and Olli, which are also eligible for the malting grades, are similar to *O.A.C.* 21 in wort quality. Pontiac, which is derived from the same stock as *O.A.C.* 21, is not regarded as equal to it in malting quality by the general standards owing to deficiencies in malt extract and enzymatic properties (3, 21). This variety is not significantly different from *O.A.C.* 21 in any one of the wort

qualities discussed, but, since its wort tends to be low in degree of attenuation and high in viscosity, it does not appear as satisfactory as *O.A.C.* 21. Peatland, which was recently removed from the malting grades, is definitely higher in initial wort turbidity than *O.A.C.* 21, and is not as good as the standard in the general summation of wort qualities. Trebi, which is avoided by maltsters for many reasons, produced more viscous worts than did *O.A.C.* 21 and, in general, its wort qualities are inferior to those of *O.A.C.* 21.

The smooth awned varieties, with two exceptions, Brandon 216 and Velvet, are definitely inferior to *O.A.C.* 21 in one or more properties. Byng, Ottawa E. 25, and Wisconsin 38 are inferior to the standard in all wort qualities.

The rating of Wisconsin 38 from the results of these investigations is of particular interest in view of the use of this variety for malting and brewing in the United States. The results of tests carried out by the Malt Research Institute in the United States on comparable samples of Oderbrucker, a sister strain to *O.A.C.* 21, and Wisconsin 38 from three crops have been published (17, 18, 19), and the authors suggest that Wisconsin 38 is as acceptable for brewing as Oderbrucker. It does not appear advisable to carry the interpretation of our analyses too far, but under Canadian conditions it appears that Wisconsin 38 is by no means equal to *O.A.C.* 21 in wort quality as defined by the measurements made in this investigation.

Brandon 216 appears to be an outstanding variety, among the smooth awned group, with respect to wort quality. It was practically identical with *O.A.C.* 21 in all respects, with the exception of initial wort turbidity in which it was higher, though not significantly so, than *O.A.C.* 21. Velvet is in a somewhat similar classification to Brandon 216, although it does not rank as high. Among the remaining varieties, worts from Newal, Nobarb, and Alberta 8 are significantly different from *O.A.C.* 21 only in viscosity, although those from Alberta 8 also tend to be low in degree of attenuation. It is of interest to note that Velvet, Newal, and Nobarb are classed as being the least unsatisfactory of the smooth awned varieties with respect to malting quality (3, 21).

As a group, the two-rowed varieties exhibit as wide ranges in wort qualities as occur in the six-rowed group. Owing to distinct differences between the groups in malting characteristics it is not advisable to lay too much stress on the direct comparisons between the two-rowed and six-rowed barleys. Comparisons within the two-rowed group are made with Hannchen as a standard since it is the most widely grown of this group and is used to some extent for brewing in the United States. In general, Hannchen appears quite similar to *O.A.C.* 21 in wort quality, although it tends to be lower in degree of attenuation and higher in viscosity. As all varieties were malted under identical conditions, which actually were developed for six-rowed varieties, and do not favour the two-rowed varieties, the differences between *O.A.C.* 21 and Hannchen are about what would be expected as a result of inadequate modification of the latter variety. The worts from Charlottetown 80 are much more turbid than those from Hannchen, and must therefore be regarded

with suspicion. Victory produces more viscous worts that tend to be less fermentable than those from Hannchen, and it is therefore considered inferior in quality. Worts from Rex, a smooth awned variety, are somewhat less viscous than those from Hannchen, but are similar to the latter in the other properties. Sanalta, also a smooth awned variety, is similar to Hannchen in degree of wort attenuation and viscosity, but the worts tend to be more turbid.

Differences Between Stations

The data for wort qualities are given in Table II as station means over all varieties. There are highly significant differences between station means, and it is therefore apparent that the environment in which the barley is produced has a considerable effect on each wort property. This was to be expected in view of results obtained with the more commonly determined barley and malt properties, and it does not seem necessary to discuss the matter further in this paper.

TABLE II

STATION MEANS FOR WORT ATTENUATION, VISCOSITY, TURBIDITY, AND STABILITY

——	Attenuation, %	Viscosity	Initial turbidity, %	Final turbidity, %	Stability
Brandon	79.2	1.47	26	172	54
Fredericton	77.1	1.52	39	167	72
Lacombe	77.1	1.54	23	164	59
Winnipeg	77.0	1.49	25	159	66
Nappan	76.8	1.67	38	125	113
Ste. Anne de la Pocatiere	75.4	1.56	70	184	86
Mean over all stations	77.1	1.52	37	162	75
Necessary difference, 5% level	0.8	0.03	12	32	30

Analyses of Variance

As noted previously, the significance of the difference between variety means and between station means was tested by analyses of variance. The statistics will not be discussed but are reported in Table III for those who are interested.

Relations Between Wort Qualities

Simple Correlations

The data in Table I indicate that intervarietal relations exist between certain wort qualities. These are illustrated in Table IV, in which the intervarietal correlation coefficients for each pair of properties are given.

Degree of attenuation is significantly correlated with viscosity only, and the relation is inverse. Viscosity in wort may be attributed to the combined effects of high molecular weight fractions of starch and protein material. Degree of attenuation is a measure of the amount of fermentable materials,

TABLE III

ANALYSES OF VARIANCE FOR WORT QUALITIES: MEAN SQUARES

Quality	Variance due to			Standard error, mean of duplicates
	Varieties	Stations	Interaction	
Attenuation, %	8.5**	35.1**	2.3	0.6
Viscosity	0.02**	0.04**	0.003	0.01
Initial turbidity, %	2420.5**	7577.6**	468.6	2.6
Final turbidity, %	11071.7**	9642.9*	3127.5	18
Stability	4431.0*	11479.0**	2703.0	18
Degrees of freedom	23	5	115	48

NOTE: *In this and later tables * denotes that the 5% level, and ** that the 1% level, of significance is attained.*

TABLE IV

SIMPLE INTERVARIETAL CORRELATION COEFFICIENTS AMONG WORT QUALITIES

Quality	Viscosity (v)	Initial turbidity, % (t_1)	Final turbidity, % (t_2)	Stability (s)
Attenuation, % (a)	−.606**	−.183	−.222	−.217
Viscosity (v)		.532**	.626**	−.685**
Initial turbidity, % (t_1)			.875**	−.646**
Final turbidity, % (t_2)				−.934**

which are low molecular weight products of starch degradation. The inverse relation between degree of attenuation and viscosity is therefore to be expected. As degree of attenuation increases, the amount of residual, unfermentable material decreases, and viscosity also decreases. The results of this investigation suggest that, between varieties, worts of high viscosity will not ferment to as great an extent as those with lower viscosity. It should be noted, however, that as only a few suitable varieties are malted and eventually brewed, it is unlikely that the range of viscosity observed in this study would be encountered in commercial brewing.

Significant correlations exist between viscosity and each of the other qualities. These also may be explained by the presence of colloidal fractions remaining after the degradation of starch and protein. The relations between the turbidity measurements are in accord with expectation, and the fact that the initial and final turbidity are quite closely related is of definite value in the laboratory. Between varieties, the initial measurement of turbidity is a good indication of final turbidity and of stability. The higher the initial turbidity, the greater is the final turbidity and the lower the stability value.

There appear to be no definite relations between attenuation and turbidity. This is surprising, since degree of attenuation is an inverse expression of the

amount of high molecular weight degradation products, and is inversely related to viscosity. However, the degree of attenuation does not indicate qualitative differences in residual, non-fermentable material, and this may be the reason for the lack of relation with turbidity. It seems worthwhile to point out that the failure to demonstrate relations between degree of attenuation and turbidity is not in accord with the results of Bishop and Whitley (5), who found that as turbidity increased, degree of attenuation decreased owing to removal of yeast from the reactions.

These workers examined 16 worts that were fermented for 120 hr. at a pitching rate of 4 to 5 gm. per litre. The worts were prepared from a single sample of malt and the differences in turbidity were brought about by combinations of differences in the rate of cooling the wort and differences due to sedimentation of the flocculum. In our investigation all worts were prepared by one method but from different malts. While Bishop and Whitley demonstrated an intravarietal relation between turbidity and attenuation among worts prepared by different methods, it does not follow that there is a corresponding intervarietal relation among worts prepared by one method. The results of the present investigation suggest that no such relation exists.

Partial Correlations

The simple correlations discussed in the previous section are subject to the limitation that two factors may appear to be related but this effect may be merely a reflection of the relations between a third factor and each of the two factors in question. Partial correlation coefficients in which the effects of other factors are removed, are therefore more stringent tests of relations than simple correlation coefficients. In order to determine whether the relations discussed in the previous section were real and independent, a number of partial correlation coefficients were computed. With one exception, these coefficients confirmed the relations already discussed. As no additional useful information was obtained, it is not necessary to report all of them.

The exception was the relations between viscosity (v), initial turbidity (t_1), and final turbidity (t_2). Neither partial coefficient ($rvt_1.t_2 = -.04$, or $rvt_2.t_1 = .39$) is significant. This is not surprising in view of the close relation between initial and final turbidities. However, the partial correlation between viscosity and final turbidity, independent of initial turbidity, approaches the 5% level of significance. This suggests that the material causing final turbidity is mainly, though not solely, responsible for the association between viscosity and turbidity, and that the relation between viscosity and initial turbidity results from the association between the latter and final turbidity.

Graphical Representation of Relations

While the correlation coefficients shown in Table IV present information on the degree of scatter of the points about the regression lines, they do so only in a general way. In order to illustrate the relations and to bring out some points that are not shown by the correlation coefficients, scatter diagrams

for the relations between viscosity and the other properties, and between initial and final turbidities are given in Fig. 1.

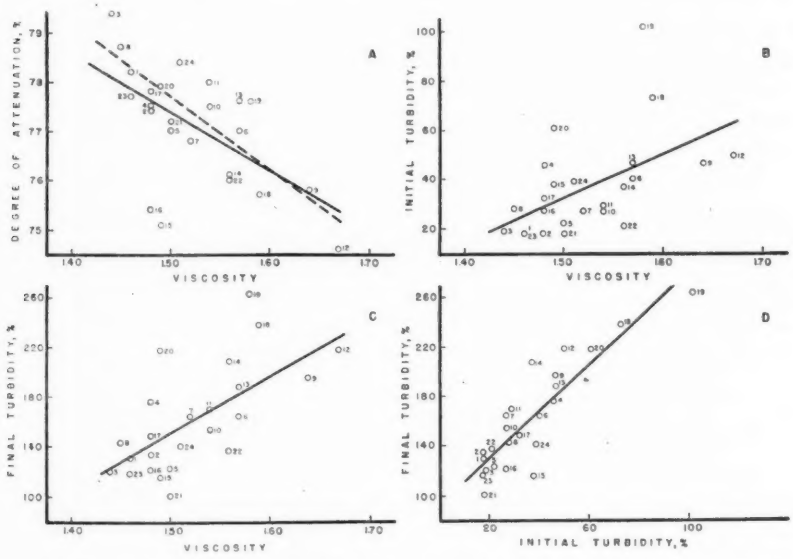

FIG. 1. *Scatter diagrams for varietal means showing the relations between wort properties. The key to varieties is given in the first column of Table I. In 1A the dotted regression line is that over 22 varieties. The heavy regression line in 1A and those in 1B, 1C, and 1D represent the regressions over all varieties.*

Fig. 1A shows that the points for two varieties, Regal and Saskatchewan 264 (Nos. 15 and 16), fall farther from the regression line than any of those for the other varieties. The intervarietal correlation coefficient, when these two varieties are omitted from the calculations, is $r = -.814$, as compared with $r = -.606$ when they are included. For both varieties the degree of attenuation is considerably less than would be expected on the basis of their viscosities. It may also be noted that the values for the stabilities of these varieties are much higher than those of any other six-rowed variety. These abnormalities suggest distinct qualitative differences between these and the other varieties in residual non-fermentable material. Judged on the basis of degree of attenuation, Regal and Saskatchewan 264 contain relatively large amounts of non-fermentable material, in fact, only one variety, Ottawa E. 25, exceeds them in this respect. However, the viscosity and stability data suggest that the constituents of the residual non-fermentable material derived from these two varieties are of lower average molecular size than those obtained from the other varieties, and this appears to account for their lower viscosity and higher stability values.

The remaining three graphs in Fig. 1 show that the scatter of the points about the regression lines is fairly uniform, with the exception of the position of No. 19 (York) in Fig. 1B.

Intravarietal Relations Between Wort Qualities

As only six stations were represented in the investigation, intravarietal relations cannot be examined satisfactorily from the data.

Application of Results

The laboratory malting test has many deficiencies, and, when the results show that a variety is promising, there is no guarantee that it will be satisfactory for commercial malting and brewing. However, there is good reason to believe that varieties selected as promising will be more satisfactory than those classed as not promising. The varieties that are considered as promising are those that are essentially similar to *O.A.C.* 21 in barley, malting, and malt properties, and definite inferiority in any important property is considered as adequate grounds for rejection of a variety (3). Additional criteria of malt quality—especially those that have a practical bearing on malting and brewing—by which the performance of a variety may be compared with that of *O.A.C.* 21, are certainly required. Among these, factors that appear to be controlled by fundamental differences between varieties are especially useful, since they may be employed in selecting promising new varieties for malting.

The wort quality determinations, degree of attenuation, viscosity, and turbidity described in this paper have been shown to differ between varieties. It is obvious, however, that there would be little point in making these determinations on new selections showing one or more serious defects in the standard laboratory malting test, since even if a variety with deficiencies in barley or malt properties proved to be similar to *O.A.C.* 21, the standard variety, in wort quality, it would still be regarded as unsuitable for malting. Undesirable characteristics of one type in a variety are not counterbalanced by desirable characteristics of another type. Hence tests on wort quality must be regarded as useful only to provide a more rigorous test of varieties that survive the standard malting test, and also to provide information of value in selecting suitable parent material in a breeding program.

While the relations between the various wort quality factors are of interest, no attempt is made at predicting one quality from another. Aside from the fact that most of the correlation coefficients obtained in this study were not high enough to permit satisfactory predictions, there is actually no practical value in attempting predictions as no time or labour is saved by this practice. The correlations are best regarded as bringing to light associations and relations between properties, and, as suggested earlier (23), information of this type may help elucidate the nature of malting quality in barley.

Acknowledgments

These studies were made possible by the co-operation of the staffs of the Agricultural Colleges and Experimental Farms listed elsewhere, who grew the samples. The authors are especially indebted to Mr. P. R. Cowan, Central Experimental Farm, Ottawa, and to Dr. P. J. Olson, the University of Manitoba, Winnipeg, Man., in whose department the work was done. The continued interest of Dr. J. Ansel Anderson in this work, and his advice on the preparation of the manuscript, are gratefully acknowledged.

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ON SOURCES OF VITAMIN C

I. ROSE HIPS[1]

By J. Tuba[2], G. Hunter[3], M. J. Hutchinson[4], and L. L. Kennedy[4]

Abstract

On the evidence of titration with 2,6-dichlorophenolindophenol, the newly ripe hips of *Rosa acicularis* contain 1800 to 3500 mg. % ascorbic acid in the wet flesh or about 4.5 to 7.6% ascorbic acid on a dry basis. The corresponding values for *R. woodsii* and *R. arkansana* are 1300 to 2000 mg. % or 4.0 to 6.0%. The hips of *R. acicularis* are the richest of the wild roses. The hips from cultivated roses have usually less ascorbic acid than the wild varieties with the exception of *R. laxa*, the richest examined, with 3000 to 4000 mg. % in the wet flesh or 8.0 to 10.3% on a dry basis.

The ascorbic acid in rose hip extracts is remarkably stable to heat and oxidation, and methods are indicated for the preparation of products suitable for winter food supplements.

The leaves and bark of wild rose bushes commonly contain 300 to 500 mg. % ascorbic acid in the fresh matter, and the petals 20 to 70 mg. %.

Introduction

Considerable work has been done in various European countries to augment the usual sources of vitamin C with naturally occurring materials that have not so far been in common use. Iwanoff and Bukin (5) report studies in the U.S.S.R. on various plant materials including rose hips. Their assays show that in rose hips there are remarkably large amounts of ascorbic acid. Similar findings have been made by British workers including Pyke and Melville (7). The reports of Shepilevskaya, Bogdanova, and Efimova (8) in the U.S.S.R., Besaric and Rikovski (1) in Yugoslavia, and a bulletin of the W.V.S. for Civil Defence in Great Britain (10) indicate some ways in which rose hips may be used in the diet. These include preparations of syrups, jams, jellies, dried powders, commercial extracts, tablets, confections, and pastry.

In these countries the matter of vitamin C supply has been one of vital importance and it is not less so in Canada. A dietary survey in Edmonton (3) and another survey among students at the University of Alberta (9) have shown that there is a definite deficiency of ascorbic acid in the diet except from June to September. The war has created problems in the matter of supplementing the diet with fruit juices and citrus fruits, and in any event, they are not always available to people with low incomes.

A brief note has already been published by us (4) on the vitamin C of rose hips and evergreens. These are winter sources and are of such importance

[1] *Manuscript received August 16, 1943.*
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that they deserve more study. We report here further vitamin C determinations on rose hips, which are not only richer in ascorbic acid than any other known natural source, but preparations from them show a remarkable stability of the vitamin. It should be mentioned that in addition to these facts the pleasant taste of the hip preparations should encourage their use in the diet.

In this paper consideration is also given to the effect on ascorbic acid values in rose hips of season, species, and locality. Some studies have been made of various methods of preserving and utilizing the ripe flesh. It was decided to confine the investigations chiefly to three species of wild roses most commonly found in Alberta. These are *R. acicularis*, which ripens earliest of the three, *R. woodsii*, which ripens next, and *R. arkansana* (or prairie rose), which is the last to ripen. In addition, some observations on cultivated roses have been recorded.

Experimental

A ripe rose hip, with stalk and flower residues removed, weighs about 1 gm. Of this about two-thirds is flesh and about one-third seeds and hairs, but this proportion differs especially with variety. In the flesh, which contains practically all the vitamin, there is about 65% water, but this decreases with the advance of the season, and, of course, under conditions that permit desiccation. In some material also we have found as much as 80% water in the flesh.

Material is analysed as soon after picking as possible. There is, however, no rapid deterioration of the fruit after picking. In material kept in a refrigerator at 5° C., awaiting analysis, there is deterioration of the fruit after several days, usually with the development of moulds. After several days in transit from distant points, the main change found has been dehydration.

Sampling

There will obviously be errors in the sampling of such material. To minimize these, the following rather arbitrary routine procedure has been used. From a batch to be analysed, eight hips are chosen, apparently as uniform as obtainable in size, ripeness, and freshness. They are split with a scalpel, the seeds and hairs are removed, and, under routine conditions, these are discarded. The flesh from two pairs is dried, and that from the other two pairs is used in duplicate vitamin C titration. Such duplicate determinations are usually close enough to yield reasonably dependable average values. When expressed on the basis of dry matter, seasonal, varietal, and like functions of the vitamin content are perhaps measurable.

Like principles have been adopted for controls in experiments on storage and the effects of other factors. For more precise controls in other tests, a dried, homogeneous powder of rose hip flesh has been used.

To evade species and varietal differences, studies have been carried out on hips picked from a single bush. These, of course, may be at different

developmental stages, as illustrated by the following determinations on a wet basis:

Green hips	666 mg. %
Semiripe hips	982 mg. %
Ripe hips	1275 mg. %

Determination

The weighed flesh of two hips prepared as above is transferred to a mortar and ground with about 10 ml. 2% metaphosphoric acid in 2 *N* hydrochloric acid until homogeneous. The mixture is transferred to a 50 ml. graduated centrifuge tube with the acid mixture washings. The volume is made up, according to weight of sample, say to 30 ml., and the material is thoroughly mixed and centrifuged. Precise aliquots of the supernatant fluid are then titrated in the usual manner with 2,6-dichlorophenolindophenol. As there is little pigment present in the extract, and a high ascorbic acid concentration, the end-point is readily determined.

Harris and Olliver (2) have shown that, if the proper precautions are taken with extraction and speed of titration, chemical and biological values for ascorbic acid are in close agreement in fruit and vegetables. They found no measurable amount of interfering substance and conclude that titration with 2,6-dichlorophenolindophenol gives accurately the total antiscorbutic activity of plant materials. There is no record of significant discrepancy between the chemical and biological assays. However, in spite of the high specificity of the method, experiments are being planned to identify more definitely the dye-reducing substance(s) in rose hips.

Results

Vitamin C in Wild and Cultivated Western Canadian Roses

A value for *R. acicularis* of 910 mg. vitamin C per 100 gm. flesh is reported by Pyke and Melville (7) in Britain, while the same species in the U.S.S.R. (5), contained 1380 mg. %. The Russian workers obtained 3186 to 6904 mg. % in the dry flesh of *R. acicularis* in the middle and northern parts of the U.S.S.R., and these dry weight values are similar to those in Table I, obtained for the same species of rose in Edmonton. For example, the two highest values, obtained from assays on November 26 and December 12, 1942, are 7602 and 6763 mg.% respectively on dry flesh. The range on the basis of dry weight is about 3000 to 7600 mg. %. The values for *R. acicularis* dropped after January 7, 1943, when the fruit was frequently mouldy, dehydrated, and leached.

The hips of *R. woodsii* and *R. arkansana*, on the other hand, did not deteriorate so rapidly, and from September to April, 1942–43, remained in good condition on the bushes. However, protection by snow and other weather factors are of importance in this regard.

TABLE I

VARIATION IN VITAMIN C OF HIPS OF WILD ROSES GATHERED DURING FALL AND WINTER IN EDMONTON

Species	Date	Vitamin C in mg. %		Water, %
		Wet flesh	Dry flesh	
R. acicularis	Sept. 12, 1942	1786	5412	60
	15	2120	6424	60
	Oct. 6	2701	6282	57
	6	1928	4484	57
	Nov. 26	3535	7602	54
	Dec. 13	4532	6763	33
	18	1783	2996	41
	21	1975	2821	30
	Jan. 7, 1943	1708	3222	47
	13	863	1288	33
	27	1530	1960	22
	Mar. 22	362		
R. woodsii	Sept. 12, 1942	1317	4000	66
	28	1666	4400	66
	Oct. 7	1350	4091	67
	7	1606	4867	67
	19	2025	6136	66
	Nov. 13	2340	4415	47
	27	1542	2537	40
	Dec. 4	1637	3031	46
	8	1869	2596	28
	9	1273	2652	52
	16	1660	3062	45
	19	2504	3794	33
	30	792	1238	36
	Jan. 6, 1943	1588	3054	48
	7	1312	2152	39
	12	1903	3965	51
	18	804	1643	51
	19	1753	2112	17
	20	916	1698	46
	26	1475	2543	43
	Feb. 2	1481	3365	56
	3	1765	2322	24
	3	1516	2757	45
	5	1685	2246	25
	5	1636	2045	21
	Mar. 16	701	935	25
	April 17	1055	1618	23
R. arkansana	Sept. 12, 1942	1317	4221	66
	Oct. 9	2135	5618	62
	9	1778	4679	62
	19	2000	6060	66
	Nov. 4	2201	5502	60
	12	2066	3552	42
	Dec. 7	848	1709	51
	Jan. 8, 1943	767	1128	32
	Feb. 1	635	1222	48
	Mar. 1	557	1161	52

From Table II it is evident that the concentration of the vitamin in the hips of cultivated roses is lower, as a general rule, than in wild ones. The one marked exception is *R. laxa*, which has the highest concentration of any

species we have examined. It is also of interest that there are few seeds present in this hip.

TABLE II

VITAMIN C DETERMINATIONS ON HIPS OF CULTIVATED ROSES

Species	Source	Date	Vitamin C in mg. %	
			Wet flesh	Dry flesh
R. altaica	Edmonton	Sept. 30, 1942	585	1773
		Oct. 27	282	972
		27	705	1410
		Dec. 29	78	170
				2068
R. blanda (Betty Bland)	Edmonton	Oct. 3, 1942	724	
				8322
R. laxa	Edmonton	Oct. 5, 1942	3096	
		27	3912	10300
		Dec. 22	3201	8650
		Jan. 28, 1943	3749	7499
		April 14	4640	6180
R. acicularis (Double Native selection)	Edmonton	Oct. 3, 1942	1041	3000
Single Petal (unidentified)	Edmonton	Aug. 31, 1942	253	—
Mrs. Simpson	Edmonton	Oct. 3, 1942	695	2200
		27	1770	3850
Rosa rugosa	Beaverlodge	Sept. 30, 1942	1454	4000
Rosa rugosa var. *hansa*	Edmonton	Sept. 30, 1942	786	2911
		Oct. 27, 1942	287	640
Rosa spinosissima	Beaverlodge	Sept. 30, 1942	594	1916
Golden Dream	Edmonton	Oct. 5, 1942	522	1373
		Dec. 17	528	1174
Hybrid (unidentified)	Edmonton	Nov. 4, 1942	1558	2000

Iwanoff and Bukin (5) have noted definite effects of altitude and latitude on the ascorbic acid content of rose hips. Pyke and Melville (7) like the Russian workers, find that the hips of roses grown in northern latitudes contain more vitamin C than those in southern. The data in Table III represent an attempt to check this correlation in Western Canada. Unfortunately our samples were too few to permit of any judgment on this point, especially as much of the material could not be classified. The data, however, serve to indicate that the Edmonton values can be regarded as representative of widely scattered areas.

Vitamin C in Relation to Preserving Methods

Effect of Cooking Utensils of Different Metals

An extensive study of methods of preserving rose hips and of utilizing them in the diet is beyond the scope of this report. However, certain preliminary observations have been made that indicate possibilities in this direction.

TABLE III

VITAMIN C IN HIPS OF WILD ROSES OBTAINED FROM VARIOUS WESTERN POINTS

Source	Date	Vitamin C in mg. %	
		Wet flesh	Dry flesh
Qu'Appelle Valley, Sask.	Sept. 17, 1942	2178	—
Whitewood, Sask.	17	1850	—
Saskatoon, Sask.	18	1320	—
Lethbridge, Alta.	19	1610	—
Beaverlodge, Alta.	21	1671	—
Beaverlodge, Alta.	29	1023	3200
Granum, Alta.	29	1276	3646
Fort McMurray, Alta.	29	1758	6511
Jasper, Alta.	Oct. 2, 1942	1129	5645
Banff, Alta.	2	1401	4670
Swift Current, Sask.	2	2126	5187
White Rock, B.C.	7	963	2675
Field, B.C.	10	1672	5573
Field, B.C.	13	1525	5247
Lethbridge, Alta.	15	1793	5603
Fort Vermilion, Alta.	22	1333	4166
Fort Nelson, B.C.	28	2326	7503
Whitelaw, Alta.	28	1306	3000

The effect of cooking rose hip flesh in vessels of various materials was examined. Dried, powdered flesh (0.5 gm.) was placed in the vessel being used in the experiment. This was covered with 20 ml. water, and the mixture boiled for 15 min., cooled, centrifuged, and acidified aliquots were titrated. The total volume was kept constant during the experiment. Tests with vessels of glass and enamel showed practically no loss of ascorbic acid (Table IV). The loss in the copper vessel is very marked, and in the aluminum less but appreciable. However, further studies should be made with cooking vessels but under conditions more closely approaching domestic usage.

TABLE IV

THE EFFECT ON THE VITAMIN C CONTENT OF POWDERED ROSE HIP FLESH OF BOILING FOR 15 MIN. IN VESSELS OF VARIOUS MATERIALS

Material of vessel	Vitamin C in mg. %	
	0 Min.	15 Min.
Glass	2938	2861 2861
Enamel	2938	2899 2899
Copper	2938	422 1457 1996
Aluminum	3256	2560 2496

Effect of Duration of Cooking

The effect of longer periods of boiling in a glass vessel is shown in Table V. After one hour of boiling the loss is only 7%. Similar experiments with whole hips indicate that there is little loss of the vitamin on prolonged boiling.

TABLE V

THE EFFECTS OF BOILING FOR VARIOUS PERIODS OF TIME ON THE VITAMIN C CONTENT OF DRIED POWDERED ROSE HIP FLESH

Time, min.	Vitamin C in mg. %	Time, min.	Vitamin C in mg. %
0	3168	30	3237
15	3191	60	2731

Storage of Hips at Low Temperatures

Hips stored in a refrigerator at 5° C. show fairly rapid deterioration. They become soft and sticky, moulds grow on them, and the level of ascorbic acid decreases. This may be illustrated by some *R. arkansana* hips which, on a basis of dry weight, on November 12, 1942, contained 3552 mg. % ascorbic acid, but by December 5, 1942, had only 2154 mg. %. These difficulties are not overcome by picking the fruit in a semiripe condition, for ripening does not go on after picking. It is thus apparent that the raw fruit cannot be preserved readily by low temperatures alone.

Rose Hip Jelly

A jelly was made from a mixture of equal parts of the juice of ripe hips and of crab apples. The juice of each was obtained by just covering the ripe fruits with water, boiling till soft, washing, and expressing. The mixture was boiled for a short time with the usual amounts of sugar and readily set on cooling. It was stored in an ordinary fruit cellar. Table VI shows that over a period of nearly 11 months there was no appreciable change in the amount of vitamin present.

TABLE VI

VITAMIN C CONTENT OF ROSE HIP AND CRAB APPLE JELLY OVER A PERIOD OF SEVERAL MONTHS

Date	Vitamin C in mg. %	Date	Vitamin C in mg. %
Sept. 8, 1942	210	April 17, 1943	206
16	225	July 19	214
Dec. 31	225		

Rose Hips Preserved in Potassium Metabisulphite

Whole rose hips, and rose hip flesh halves were preserved in a series of Erlenmeyers, containing an aqueous solution of a commercial preservative

consisting of potassium metabisulphite with a lactose binder. The glass vessels were stoppered with corks which were then waxed. The preserved material was kept in the refrigerator and periodically flasks were opened for assays on the whole hips and on the flesh. The hips lost some of their colour, but remained quite firm. Table VII indicates that the vitamin values are not much changed from the time of preserving on Sept. 23, 1942, until the end of March, a period of six months. The rather erratic values, especially in Series I, is traceable probably to lack of uniformity of material.

The vitamin C determinations were modified to overcome the reducing effect of metabisulphite according to the method of Mapson (6).

TABLE VII

VITAMIN C CONTENT OF ROSE HIPS PRESERVED IN POTASSIUM METABISULPHITE OVER A PERIOD OF SEVERAL MONTHS

——	No. of flask	Date of assay	Vitamin C in mg. %
Series I			
Whole hips	Control	Sept. 23, 1942	1053
	1	Nov. 30	827
	2	Dec. 2	1092
	3	Jan. 21, 1943	940
	4	Mar. 12	766
	5	31	1084
Series II			
Flesh	Control	Sept. 23, 1942	1435
	1	Nov. 28	1405
	2	Jan. 12, 1943	1315
	3	Mar. 9	1296
	4	30	1169

Dehydration

Table VIII shows the results of dehydration of rose hip flesh at different temperatures. From the vitamin assay it appears that the best temperature tested is 80° C., the recovery of vitamin C being 80% of the total. Our experience with other materials under like conditions would suggest that this is more than can be expected from most fruits and vegetables.

TABLE VIII

THE EFFECT OF DRYING AND OF TEMPERATURE ON ROSE HIPS

Temperature	Material dried	Dried matter, %	Time of drying, hr.	Vitamin C remaining in dried flesh, %
48 to 50	Flesh	36.0	28	66.6
78 to 80	Flesh	32.7	6	80.7
105 to 109	Flesh	32.1	6	56.7

The dried flesh was stored as follows: (1) uncrushed, (2) crushed in a mortar until fine enough to pass through a 40 mesh sieve. Powders containing as much as 5.3% of vitamin C were obtained in this way. The powders and the uncrushed, dehydrated flesh were stored in a refrigerator and were assayed from time to time during the winter. The results are shown in Table IX.

It is perhaps surprising that there is such a marked loss of the vitamin in view of the facts that the dried materials were stored in a refrigerator, and the greater stability of the ascorbic acid noted in the jelly described (Table VI) and stored at room temperature. In a period of 10 months the range of loss is 18 to 45% in the dried flesh, and there is a somewhat smaller loss of 10 to 30% in the powdered material. Besaric and Rikovski (1) report a loss in eight months of "not over 50%" in dried rose hips.

TABLE IX

VITAMIN C LEVEL IN DEHYDRATED FLESH OF ROSE HIPS OVER A PERIOD OF SEVERAL MONTHS

Number of experiment	Date of assay	Vitamin C in gm. %	
		Dried flesh	Dried powdered flesh
1	Sept. 30, 1942	5.3	5.3
	Dec. 11	5.2	4.8
	Jan. 23, 1943	4.9	4.5
	Mar. 25	3.8	4.1
	Aug. 4	2.9	3.7
2	Oct. 2, 1942	3.6	3.6
	Dec. 11	3.3	3.2
	Jan. 23, 1943	3.3	3.3
	Mar. 11	2.8	3.3
	Aug. 4	2.9	3.2
3	Oct. 14, 1942	4.2	4.2
	Dec. 11	3.7	3.4
	Jan. 23, 1943	3.0	3.1
	Mar. 11	3.2	3.0
	July 6	—	3.0
	Aug. 4	2.3	3.0
4	Oct. 14, 1942	—	3.8
	Dec. 14	—	3.4
	Jan. 23, 1943	—	3.1
	Aug. 4	—	3.0

Vitamin C in Bark, Leaves, and Petals of Roses

Because rose hips are so high in their content of vitamin C, the bark of the bushes was also assayed, and, later in the year it was again examined as were the leaves and the petals of the flowers. Table X shows the results. In all cases the petals have much less than the bark or leaves, which are relatively rich in the vitamin. The young leaf has less than the fully grown.

TABLE X

VITAMIN C IN THE BARK, LEAVES, AND PETALS OF VARIOUS SPECIES OF ROSES

Species	Tissue assayed	Date	Vitamin C in mg. % of fresh material
R. woodsii	Leaves	May 25, 1943	398 501
	Leaves	May 28, 1943	372 370
	Leaves	June 11, 1943	460 416
	Leaves	June 29, 1943	451 580 575
	Bark	Jan. 14, 1943	235 465
	Bark	May 28, 1943	359 338
	Petals	July 7, 1943	63 68
R. acicularis	Leaves	May 29, 1943	285 377
	Leaves	June 12, 1943	460 393
	Leaves	June 28, 1943	423 414
	Bark	Jan. 14, 1943	293 387
	Bark	May 29, 1943	147 158
	Petals	June 25, 1943	22 39
R. arkansana	Leaves	May 28, 1943	285 286
	Leaves	June 29, 1943	330 327
	Bark	May 31, 1943	221 248
	Petals	July 14, 1943	51 64 76

TABLE X—*Concluded*

VITAMIN C IN THE BARK, LEAVES, AND PETALS OF VARIOUS SPECIES OF ROSES—*Concluded*

Species	Tissue assayed	Date	Vitamin C in mg. % of fresh material
R. altaica	Leaves	July 6, 1943	413 347 378
R. laxa	Leaves	July 6, 1943	322 371 367
	Petals	July 12, 1943	159 147 133

Acknowledgments

The authors wish to express their thanks to Dr. J. S. Shoemaker, Department of Horticulture, University of Alberta, for supplying and identifying rose hips of cultivated species, and to Dr. E. H. Moss, Department of Botany, University of Alberta, Edmonton, Alta., for information regarding wild species of roses.

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CANADIAN JOURNAL OF RESEARCH

VOLUME 21
1943
SECTION C

CANADA

Published by the
NATIONAL
RESEARCH COUNCIL
of CANADA

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Canadian Journal of Research

Issued by THE NATIONAL RESEARCH COUNCIL OF CANADA

VOL. 21, SEC. D. DECEMBER, 1943 NUMBER 12

DRIED WHOLE EGG POWDER

IX. EFFECT OF DRYING CONDITIONS ON QUALITY[1]

BY A. H. WOODCOCK[2] AND MARGARET REID[3]

Abstract

Liquid whole egg was spray dried in a small, laboratory drier at various flow rates of liquid egg and at different inlet and exhaust air temperatures. Quality of the powder, as assessed by chemical methods, palatability, and baking tests, was progressively improved as the exhaust air temperature was lowered. Inlet air temperatures above 107° C. (225° F.) had a deleterious effect. Lowering the drying temperature, however, had an adverse effect on the rate of production.

Introduction

The necessity of producing large quantities of high quality egg powder in a relatively short time has resulted in the operation of egg-drying plants by somewhat arbitrary methods. Apparently little systematic study has been made of factors affecting the production of the maximum quantity of powder compatible with good quality in the cyclonic type of spray drier. Accordingly, experiments were made with a laboratory model spray drier (6) and it is hoped that these will be of some value in guiding commercial egg-drying plants in the production of first grade powder. The factors affecting spray drying of egg powder described in this paper are: inlet and exhaust air temperatures and flow rate of liquid egg.

Materials and Methods

Grade *A* Large eggs obtained from the open market were used exclusively throughout these experiments. The eggs were broken and the whites and yolks thoroughly mixed by mechanical stirring at a low speed to prevent frothing. Chalazae, yolk membranes, and shell membranes were removed by straining through cheese cloth and a fine wire screen.

Three series of measurements were made involving three variables, namely, flow rate of liquid egg into the drier, and inlet and exhaust air temperatures. In each series one of the three variables was held constant while the other two were varied dependently. In the first series the flow rate of the liquid

[1] *Manuscript received September 7, 1943.*

Contribution from the Division of Applied Biology, National Research Laboratories, Ottawa. Issued as paper No. 102 of the Canadian Committee on Food Preservation and as N.R.C. No. 1162.

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egg was held approximately constant while the inlet air temperature was varied in 14° intervals from 79° C. (175° F.) to 135° C. (275° F.). In the second series the inlet air temperature was held constant at 121° C. (249° F.) and the flow rate of liquid egg was varied, resulting in a range of exhaust air temperatures. The third series was arranged with inlet temperatures from 66° C. (150° F.) to 135° C. (275° F.) in 14° intervals while the flow rate of liquid egg was adjusted to give an exhaust air temperature of 60° C. (140° F.).

Quality of the powder was assessed by determinations of the moisture content, fluorescence, potassium chloride, and refractometric values, and palatability ratings by methods already described (2, 3, 4) and by baking tests.

The baking quality of the product was assessed by measuring the volume of sponge cakes made from the various powders. These sponge cakes were made with 12 gm. of dried egg, 40 gm. of white sugar, 40 gm. of white flour, and 38 ml. of water. The dried egg and sugar were mixed thoroughly before adding the water, thus preventing the formation of lumps in the mixture. This was then beaten at high speed in a "Mixmaster" for 10 min. After beating, the flour was added with sufficient mixing at the lowest speed to give a homogeneous batter. The cake was baked for 35 min. in an oven at 163° C. (325° F.). The volume of the cake was measured in terms of the volume of rape seed displaced (1).

Results

Table I shows the results of varying the inlet air temperature while the rate of flow of liquid egg was held constant. It may be seen that the exhaust air temperature decreased as the inlet air temperature was lowered but that the drop in temperature was not constant. This might be expected since, in a small experimental drier, the ratio of surface area to volume is high, resulting in appreciable heat loss through the walls.

TABLE I

EFFECT OF INLET AND EXHAUST AIR TEMPERATURES ON THE QUALITY OF SPRAY DRIED WHOLE EGG

Air temperature				Flow rate of liquid egg, ml./min.	Quality measurements					
Inlet		Exhaust			Moisture content, %	Fluorescence value	Potassium chloride value	Refractometric value	Palatability score	Cake volume, ml.
° C.	° F.	° C.	° F.							
134	274	84	184	33.8	1.09	37.3	45.7	234	7	287
122	251	79	175	31.1	1.14	30.6	60.1	248	8	296
107	225	69	156	32.7	2.08	18.8	70.0	266	8	317
94	201	58	137	30.1	2.82	15.2	73.9	267	8½	383
79	175	50	122	27.2	3.08	14.2	78.1	265	8½	434

The moisture contents of the egg powder increase with decreasing air temperatures. This is due to the lower capacity for moisture of cooler air and the slower rate of evaporation.

The quality of the resulting egg powder, as shown by chemical methods, palatability, and cake volume, increased with decreasing air temperatures. Cake volume is also shown in Fig. 1.

Table II indicates the effect of lowering the exhaust air temperature while holding the inlet air temperature constant. It will be seen that lowering the exhaust air temperature considerably increased the rate of production. Again, owing to heat losses through the walls of the drier, the drop in temperature of the air passing through the drier was not proportional to the flow of liquid egg. As the exhaust air temperature was reduced the moisture content of the resulting egg powder was increased. This was due to both the greater absolute amount of moisture to be removed and the lower moisture capacity of the cooler exhaust air.

TABLE II

EFFECT OF EXHAUST AIR TEMPERATURE ON THE QUALITY OF SPRAY DRIED WHOLE EGG

Air temperature				Flow rate of liquid egg, ml./min.	Quality measurements					
Inlet		Exhaust			Moisture content, %	Fluorescence value	Potassium chloride value	Refractometric value	Palatability score	Cake volume, ml.
°C.	°F.	°C.	°F.							
121	249	76	168	35.1	1.18	28.8	56.3	248	8	284
121	249	71	160	43.1	1.59	28.0	57.6	254	8	412
121	249	67	152	52.6	1.81	23.1	60.4	256	8	418
121	249	62	144	64.4	3.71	20.2	59.8	262	8½	421

Quality as determined by fluorescence and refractometric values and cake volume (Table II) showed a regular increase in quality as the exhaust air temperature was lowered. The potassium chloride values and palatability ratings were somewhat irregular. All these criteria however showed a definite trend toward a higher quality product when the exhaust air temperature was lowered.

Table III shows the effect of lowering the inlet air temperature while maintaining a constant exhaust air temperature. The effect on production

TABLE III

EFFECT OF INLET AIR TEMPERATURE ON THE QUALITY OF SPRAY DRIED WHOLE EGG

Air temperature				Flow rate of liquid egg, ml./min.	Quality measurements					
Inlet		Exhaust			Moisture content, %	Fluorescence value	Potassium chloride value	Refractometric value	Palatability score	Cake volume, ml.
°C.	°F.	°C.	°F.							
121	250	60	140	59.5	1.93	17.1	64.7	261	8	420
107	225	60	140	47.5	2.01	17.4	63.4	264	8½	444
93	200	60	140	32.6	1.78	19.2	63.7	258	8½	453
79	175	60	140	16.4	2.05	17.6	70.3	258	8	447

was very marked and again the drop in air temperature indicated loss of heat through the walls of the drier. Altering the inlet air temperature appears to have little effect on the moisture content. Two counteracting phenomena caused this: with higher inlet air temperatures more moisture was evaporated with consequently moister exhaust air, and at the higher temperatures evaporation was more rapid.

The quality measurements in general showed irregular changes, the differences being hardly distinguishable from experimental errors. When the temperature was reduced from 124° C. (250° F.) to 107° C. (225° F.) the fluorescence and potassium chloride values showed no significant change. However, quality as tested by the refractometric value, palatability, and especially cake volume, however, did show some improvement. Further lowering of the inlet air temperature effected little change in quality until a temperature of 79° C. (175° F.) was reached. At this temperature there was suggestion of a decrease in quality. It is probable that this is due to the very low flow rate of the liquid egg. When the rate is reduced, a greater proportion of the egg powder temporarily sticks to the walls of the drier and suffers some thermal deterioration.

Discussion

From the above results it will be seen that the drop in temperature of the air passing through the drier is dependent on the rate of production. In full scale commercial driers where the loss of heat through the walls is negligible the drop in temperature is essentially proportional to the rate of production. It is therefore advisable in order to secure maximum production to use the highest inlet air temperature and lowest exhaust air temperature compatible with the quality desired.

The drop in temperature desired in drying egg is dependent on good initial quality and low moisture content. The moisture content has been shown to be closely connected with the keeping quality (5). Lowering the outlet temperature has been shown in Tables I and II to increase the moisture content.

Initial quality has been shown to be directly related to exhaust air temperature. This effect is not so marked in the second series of experiments (Table II) as in the first (Table I), since the range of exhaust air temperatures is much less in the second series. Table I indicates that exhaust temperatures below 60° C. (140° F.) were required in order to obtain first quality powder. Table III indicates that the maximum inlet air temperature for first quality powder was between 107° C. (225° F.) and 121° C. (250° F.).

While these data have been obtained on an experimental drier they should be generally applicable to commercial plants since exposure of egg particles to warm air is the primary factor in drying. Some variation in their actual magnitudes can, however, be expected, particularly in moisture content.

PLATE I

FIG. 1. *Increase in cake volume with decrease in drying temperatures.*

Acknowledgment

The authors wish to express their thanks to Mr. H. Tessier, Laboratory Assistant, for his valuable technical aid in carrying out the drying operations.

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THE DEHYDRATION OF PORK[1]

By Jesse A. Pearce[2]

Abstract

Four preprocessing and three drying procedures for the dehydration of pork were studied. The best product resulted from cooking in an open steam-jacketed kettle, followed by mincing and tunnel–tray drying in four hours or less with a tray load of 2 lb. per square foot. Little difference in quality of the product was observed for air velocities of 700 to 1200 ft. per min. over the trays, or for initial stage temperatures between 70° and 80° C. and final stage temperatures between 55° and 70° C.

Pork, when dried to a moisture content of 3 to 4% in less than four hours, still retained a high percentage of the thiamin present in the raw meat, showed no fat deterioration when assessed by peroxide oxygen determinations, and on reconstitution had a palatability rating approximately equal to that of the initial cooked material.

Introduction

General interest has been aroused in the dehydration of food products as a means of conserving shipping space and packaging materials. In addition, dried foodstuffs show greater resistance to spoilage during storage and transport. This study was confined entirely to the dehydration of pork, as pork is the only meat that is produced in substantial quantities in Canada at the present time. When these studies were undertaken little information was available on pork dehydration. This paper describes the effect of various preprocessing treatments and methods of dehydration on the quality of dried pork.

Materials

Uncured sow ham was used for the greater part of this investigation, as it was felt that this material was representative of the type of pork likely to be dried. In addition, separation of meat from fat and bone is more easily and cheaply accomplished in the ham than in other cuts. Some export cured ham was also dried for comparison with the uncured dried product.

Precooking Procedure

Initially, uncured sow ham was tunnel–tray dried under four conditions: coarsely minced meat, and meat in chunks of approximately 2 cu. in., were dried both with and without precooking. The results are shown in Table I. Although the drying conditions were found to be impractical in subsequent work, Table I indicates that, for drying purposes, cooked minced meat was a superior starting material. In addition, it was believed that dried chunks would cause packaging difficulties; therefore cooked minced meat was finally

[1] *Manuscript received August 26, 1943.*

Contribution from the Division of Applied Biology, National Research Laboratories, Ottawa. Issued as Paper No. 103 of the Canadian Committee on Food Preservation and as N.R.C. No. 1172.

[2] *Biochemist, Food Investigations.*

chosen as the most suitable material for drying, in spite of the significant decrease noted in the palatability score.

TABLE I

EFFECT OF METHOD OF PREPARATION ON DRYING RATE AND FINAL QUALITY

Temperature, 93° C.; air flow, 900 ft. per min.; tray load, 2 lb. per sq. ft.

Condition of meat	Relative humidity of tunnel air (%)			Over-all drying rate (% per hr.)	Drying time (hr.)	Quality of dried product			
	Initial	Drying 2/3 complete	Final			Moisture content (%)	Palatability score		Peroxide oxygen value (ml. 0.002 *N* thio-sulphate)
							Initial	After drying	
Chunks, raw (1" × 1" × 2")	53	22	21	10	9	15	7.5	6.6	13
Chunks, raw[1] (1" × 1" × 2")	68	34	32	9	10	21	7.5	6.1	5.4
Chunks, cooked (1" × 1" × 2")	47	22	18	10	8	23	7.5	6.9	14
Minced, raw	50	24	29	13	6.5	24	7.8	7.4	11
Minced, cooked	66	27	24	12	8	2.0	7.8	5.3	4.2
Minced, cooked[1]	60	33	35	13	7.5	2.0	7.9	4.0	0

[1] *Smoke added for two hours at the commencement of drying.*

Throughout this work pork was considered to be sufficiently precooked when redness had just disappeared from the centre of meat chunks or of a mass of minced meat. Meat was minced using a Hobart grinder with a $\frac{3}{8}$ in. plate.

Four precooking procedures were investigated. The first method involved separating the meat from bone, fat, and rind, mincing, and cooking for three minutes per pound at 15 lb. pressure. Meat prepared in this way was very wet, dripped badly in the initial stages of drying, and dried slowly, forming large, spongy aggregates in the process. A test sample of meat prepared by this method retained 83% of the thiamin present in the raw meat.

The second method involved cutting the whole ham to the bone at 3- or 4-in. intervals, and cooking at 93° to 104° C. (200° to 220° F.) in a retort, allowing 20 min. per pound. The meat was then separated from bone, fat, and rind, minced, and dried. Although export cured ham could be handled by this method, the greater bulk and heavier fat layers of the larger sow ham prevented its satisfactory use. Preparation of meat in this manner avoided the formation of spongy aggregates during the drying process.

The third procedure involved separating the meat from bone, fat, and rind, and cutting it into slices 1 in. thick, each weighing about a pound. These slices were placed on trays to a depth of about 4 in. and cooked in a retort for 20 to 30 min. at 15 lb. steam pressure. The cooked slices were removed

and minced. The liquor separating from the meat was collected and concentrated to about one-quarter its original volume and mixed with the mince before drying.

The fourth method, open pot cooking, eliminated separate concentration of liquor. A steam-jacketed kettle (15 lb. steam pressure in the jacket) replaced the trays and retort. The meat was cooked without added water and with constant stirring (allowing about one minute per pound of meat). Pork cooked by this method was observed to contain 87% (σ = 6%) of the thiamin present in the raw material.

Moisture contents and palatability scores of pork, prepared for drying by each of the different methods, are compared in Table II. It is evident that there is no significant difference in the palatability of pork cooked by any method studied. The last procedure was considered the most practical for dehydration purposes because of the lower moisture content of the material going into the drier.

TABLE II

MOISTURE CONTENTS AND ORGANOLEPTIC RATINGS OF PORK PREPARED FOR DRYING BY DIFFERENT METHODS

Method of preparation	Moisture content (%)		Palatability score
	Mean	Standard deviation	
Raw pork	71	4	
Cooked chunks			8.3
Minced pork, pressure cooked	68	3	7.6
Whole, cured ham cooked, then minced	66	2	8.3
Pork chunks, pressure cooked, liquors concentrated and added back to minced meat	61	3	8.1
Pork chunks, cooked in open kettle and minced	56	3	8.3

Method of Drying

Three types of drying apparatus, representing those most likely to be available for commercial purposes, were studied.

Dried pork was produced by vacuum (26 in. gauge)–tray drying at 71° and 82° C. (160° and 180° F.), with a loosely spread meat load of 2 lb. per square foot.

Investigations were also carried out using a laboratory model atmospheric, double-drum drier. The drums were 6 in. in diameter and the meat was in contact with the drums for two-thirds of one revolution. Steam pressure in the drums was varied between 15 and 60 lb. (gauge); speed of rotation from 0.25 to 3.0 r.p.m.; and spacing between the drums between $\frac{1}{16}$ and $\frac{1}{64}$ in.

Experimental tunnel driers were used for the greater part of the investigation. The smaller laboratory tunnel–tray drier accommodated 12 sets of trays 6 × 8 × 1 in. The trays were arranged in three tiers with 1 in. intervals between them to allow free passage of the air over the meat. For convenience

in measuring the weight decrease without interrupting the drying process, the set of trays rested on the platform of a scale. Temperatures of drying were varied between 49° and 93° C. (120° and 200° F.). The air velocities used were 300, 600, and 900 ft. per min. in the open tunnel, corresponding to 400, 800, and 1200 ft. per min. over the trays. High humidities were obtained by closing the tunnel, and low humidities by changing the air in the drier 15 or 16 times per min. on a volume basis. Reduction of the meat load from 2 to 1 lb. per square foot and stirring the meat were tried in an attempt to reduce the time of drying. Smoke was added in some cases during drying, with the hope of retarding deterioration in the fat (4).

Following favourable indications obtained with this small tunnel drier, drying by this method was attempted on a larger model. The larger tunnel drier accommodated 28 trays 12.5 × 20 × 1 in., arranged in four stacks of seven tiers. Again 1 in. spaces were allowed for passage of air. The air flow in the open tunnel was 500 ft. per min. which corresponded to 700 ft. per min. over the trays. The air in the tunnel was changed about 15 times per min.

Analytical Methods

Most of the quality measurements at present used on dried foods are considered to be inadequate. Fat content was considered to be of minor importance since it was felt that hams could not easily be trimmed to any given fat content. The fat content of the trimmed meat averaged 31% (σ = 9%) on a dry matter basis. For dried pork the features believed to have the greatest significance were palatability, the quality of the fat, and amount of thiamin retained.

Moisture Content.—Moisture content was determined by vacuum drying 5-gm. samples for 16 hr. at 100° C.

Fat Content.—Petroleum-ether–soluble materials were used as a measure of the fat content. Fifty-gram samples were extracted in a Soxhlet for 16 hr.

Peroxide Oxygen Value.—This determination had been found satisfactory for deterioration in pork fat (1). The method has been described (3). The value observed for the initial material, whether raw or cooked, was zero ml. 0.002 *N* thiosulphate per gram of extracted fat.

Thiamin Content.—A method of determining thiamin in meat and meat products (2) proved satisfactory for the present work. Five-gram samples of raw or cooked materials and 2-gm. samples of dried materials were used. For convenience, the results are given as percent of thiamin retained in the dried product, calculations being based on the amount present in the initial cooked material (*D.M.B.*).

Palatability Score.—The reconstituted samples were given organoleptic ratings by a panel of 14 tasters. Panel members tasted the unsalted, reconstituted product and scored as follows: 10, for excellent fresh pork; 8, fair fresh pork; 6, poor pork that could be eaten if necessary; 4, definitely unpleasant; 2, repulsive. (Intermediate scores and zero could be applied.)

It was observed that the necessary difference for significant change in the edibility of the meat varied from about 0.8 to 1.2 palatability units, at the 5% level of statistical significance. Therefore, in making general comparisons, differences greater than 1.0 palatability units are considered significant.

Results

Vacuum–Tray Drying

The conditions of vacuum–tray drying and the results of analyses on the dried product are given in Table III. Drying was considered complete when the rate of loss reached about 0.2% per hour. The extended drying period, high peroxide oxygen values for the fat, decrease in edibility, and retention of only a small fraction of the thiamin originally present indicated the impracticability of this type of drying. Analysis of the distillate showed the presence of 48% of the thiamin originally present in the cooked meat. As the distillate had the odour and flavour of a fairly good meat broth, a large proportion of the materials contributing to flavour were believed to be lost during drying.

TABLE III

VACUUM–TRAY DRYING—MINCED SOW HAM COOKED (UNCURED)

Vacuum, 26 in. gauge; tray load, 2 lb. per sq. ft.

Dry bulb temp.	Over-all drying rate (% per hr.)	Drying time (hr.)	Moisture content (%)	Quality of the dried product			
				Peroxide oxygen value	Palatability score		Thiamin retained (%)
					Initial	After drying	
71° C. (160° F.)	3	30	24	22	7.9	6.5	
82° C. (180° F.)	4	23	9.1	6.7	7.9	7.1	21

Atmospheric Double-Drum Drying

Drum drying yielded a flaky product that on reconstitution failed to reabsorb as much water as samples prepared by the other methods. Analyses of the dehydrated material (Table IV) indicated that it was difficult to obtain a really dry product. In many instances, the fat present in dried material had excessive peroxide oxygen values. Occasional palatability tests showed the reconstituted product to have a poor texture although it had a not unpleasant resistance to chewing.

Tunnel–Tray Drying—Small Drier

As there was little information available on the dehydration of pork, it was assumed initially that tunnel drying demanded relatively high humidities and small initial temperature increments to minimize case hardening and deterioration of the fat. Table V shows such conditions of drying and quality measurements for uncured sow ham and export cured ham. Drying was considered

TABLE IV

DOUBLE DRUM DRYING—MINCED SOW HAM COOKED (UNCURED)

Steam pressure in drums (lb. gauge)	Drum speed (r.p.m.)	Space between drums (in.)	Approximate rate of processing (lb. per hr.)	Quality of dried product				
				Moisture content (%)	Palatability score		Peroxide oxygen value	Thiamin retained, (%)
					Initial	After drying		
15	3.00		36	51			25	
30	3.00		36	44	7.9	7.1	14	
30	1.50	1/64	11	33			28	97
30	0.25	1/32	2	15	8.3	7.0	1.0	60
60	1.50	1/64	14	18			4.6	87
60	1.50	1/32	21	28			3.7	81
60	1.50	1/16	21	31			2.6	81
60	0.25	1/64	2	2.9	8.3	6.0	1.9	20

TABLE V

TUNNEL-TRAY DRYING—MINCED HAM, COOKED

Tray load, 2 lb. per sq. ft.

Material	Dry bulb temperature	Relative humidity of tunnel air (%)			Air flow (ft./min.)	Overall drying rate (% per hr.)	Drying time (hr.)	Quality of the dried product				
		Initial	Drying 2/3 complete	Final				Moisture content (%)	Palatability score		Peroxide oxygen value	Thiamin retained (%)
									Initial	After drying		
Uncured sow ham	93° C. (200° F.)	56	27	24	900	12	8	2.0	7.8	5.3	4.2	16
	82° C. (180° F.)	50	31	27	900	11	9	4.8	7.8	7.6	7.4	21
	71° C. (160° F.)	64	34	30	900	10	10	7.4	7.0	7.2	7.8	26
	71° C. (160° F.)	40	11	8	600	11	9	2.9	6.2	6.2	29	
	71° C.[1] (160° F.)	64	40	32	900	14	7	6.5	7.9	7.6	16	
	71° C.[1] (160° F.)	72	53	38	900	23	4	17	6.2	6.4	17	
	60° C. (140° F.)	52	22	20	900	9.3	10	5.7	7.2	7.2	23	
Export cured ham	71° C. (160° F.)	54	46	44	300	12	8	5.7	8.8	7.5	8.3	
	71° C. (160° F.)	62	38	38	600	11	8.5	9.9	8.7	8.0	14	
	71° C. (160° F.)	54	40	39	900	12	8	3.8	8.8	7.9	10	
	71° C.[2] (160° F.)	64	47	48	900	13	7	12	8.6	7.9	17	
	93° – 71° C.[3] (200–160° F.)	57	24	33	900	15	6	19	8.6	8.6	3.4	

[1] *Drying stopped arbitrarily.*

[2] *Meat stirred on trays every two hours.*

[3] *Higher temperature for four hours, low temperature for remainder of period.*

complete when the rate of weight loss reached about 0.2% per hour. During drying, the humidity dropped rapidly for the first two-thirds of the period and slowly for the remainder of the time.

Although drying by this procedure could not be considered satisfactory, the results yielded information of value. Comparison of the palatability of the dried products obtained from the two types of ham indicated that export cured ham suffered greater deterioration than sow ham. The optimum drying temperature seemed to be 71° C. (160° F.). Different air velocities had no pronounced effect on the rate of drying. Stirring the meat during drying effected no improvement either in drying time or quality of product.

The addition of smoke to the air stream for two hours at the commencement of the run reduced the peroxide oxygen values observed in the fat, but resulted in decreased palatability scores (Table I).

It appeared advisable at this stage to determine the behaviour of the fat and the temperature changes occurring in the meat during a typical drying run. Table VI shows the data obtained when peroxide oxygen values of the fat were measured at intervals during drying. These results indicated that from the point of view of fat quality the drying period should be no greater than four hours. However, the peroxide oxygen measurement, when applied to fat extracted from dehydrated pork was unsuitable as an indication of eating quality (Table V).

TABLE VI

CHANGE IN PEROXIDE OXYGEN VALUE OF FAT DURING TUNNEL–TRAY DRYING

Temperature, 71° C. (160° F.); air flow, 900 ft. per min.

Time (hr.)	Peroxide oxygen value
Uncooked fat	0
Cooked fat (zero time)	0
2.0	0
4.0	0
5.0	1.9
6.0	4.2
7.0	4.6
8.0	6.7

Fig. 1 shows the temperature changes occurring throughout the meat as drying proceeds. It is evident from these results that variations in temperature existed within trays of meat as well as between trays. Evaporation from the wet meat caused a rapid drop in air temperature. The over-all temperature drop, with an air flow of 1200 ft. per min., over four columns of trays of meat, loaded to 2 lb. per square foot, was about 11° C. (20° F.). It was evident from the fact that the meat assumes the temperature of the wet bulb at the start of drying that much higher temperatures might be used initially.

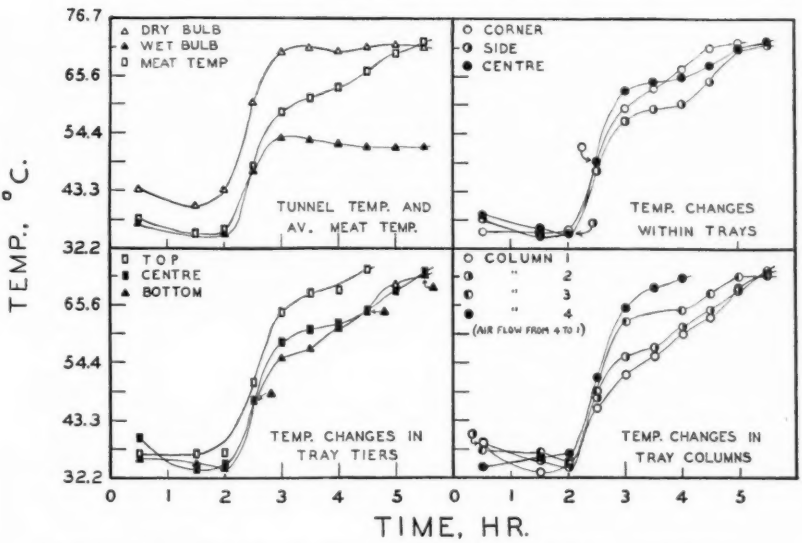

FIG. 1. *Temperature changes occurring in trays of minced pork during dehydration.*

As a result of the above observations the method of tunnel–tray drying was modified and applied only to uncured sow ham. Methods of cooking that effectively reduced the moisture content were used (cf. Table II). In general, the data obtained (Table VII) indicate that drying at temperatures of about 54° C. (130° F.) and with low relative humidities results in a dried product of better quality as assessed by objective measurements. The use of temperatures as high as 82° C. (180° F.) for a short period at the start of drying caused no marked deterioration in the product. Reduction of the meat load from 2 to 1 lb. per square foot decreases the drying time only slightly. For drying under conditions studied here, an air flow of as low as 300 ft. per min. would greatly reduce the output, but either 600 or 900 ft. per min. would be satisfactory. Pronounced increase in the amount of thiamin retained in the dried product resulted from the use of these shorter drying times and lower drying temperatures (cf. Tables V and VII). Samples of the material dried at 54° C. (130° F.) and of the initial material, when submitted to the tasting panel, were scored 7.9 and 8.3 palatability units respectively, the difference being quite insignificant.

It was observed that the cooked product must be introduced into the drier immediately after cooking and mincing, as allowing the cooled meat to stand resulted in the development of off-odours and flavours that persisted in the dried product, rendering it unpalatable when reconstituted. When holding for short periods was necessary, 93° C. (200° F.) was found to be a convenient and satisfactory temperature.

TABLE VII

TUNNEL–TRAY DRYING—COOKED MINCED SOW HAM (UNCURED)

Conditions under study	Dry bulb temperature	Relative humidity of tunnel air (%)			Meat load (lb./ft.)	Air flow (ft./min.)	Overall drying rate (% per hr.)	Quality of dried product		
		Prior to run	Initial	Final				Moisture content (%)	Peroxide oxygen value	Thiamin retained (%)
Drying time—four hours										
Variation in temperature and humidity	93° C. (200° F.)	6	8	9	2	900	25	2.0	11	60
	93° C. (200° F.)	7	17	6	2	900	25	2.0	16	63
	71° C. (160° F.)	6	19	7	2	900	24	3.9	8.4	71
	71° C. (160° F.)	18	35	15	2	900	24	5.7	12	70
	49° C. (120° F.)	16	50	17	2	900	23	13	0	70
	49° C. (120° F.)	26	65	50	2	900	18	30	8.8	75
Drying time—three hours										
Variation in temperature and meat load	54° C. (130° F.)	19	40	19	1	900	32	3.8	1.0	97
	54° C. (130° F.)[1]	29	60	46	2	900	30	13	0	72
	60° – 49° C.[2] (140° – 120° F.)	16	32	24	1	900	30	12	1.2	52
	60° – 49° C.[2] (140° – 120° F.)	14	36	24	2	900	31	8.3	0	89
	71° – 49° C.[2] (160° – 120° F.)	11	27	23	1	900	32	5.7	0	74
	71° – 49° C.[2] (160° – 120° F.)	13	30	22	2	900	32	4.8	3.9	68
	82° – 54° C.[2] (180° – 130° F.)	10	18	45	1	900	32	5.7	0	64
Variation in air flow	82° – 54° C.[2] (180° – 130° F.)	9	30	21	2	900	31	11	0	75
	82° – 54° C.[3] (180° – 130° F.)	18	34	46	2	600	31	9.1	0	91
	82° – 54° C.[3] (180° – 130° F.)	20	24	37	2	300	26	26	0	88

[1] *Stirring at half hour intervals gave results no different from those recorded.*

[2] *Two hours at the higher air temperature.*

[3] *One hour at the higher air temperature.*

Tunnel–Tray Drying—Large Drier

The favourable results obtained with the small drier led to an attempt at drying pork on a larger scale. It was hoped that conditions similar to those described above would be satisfactory for the larger drier. Fresh sow ham was cooked and minced before use in this apparatus and the tray load was 2 lb. per square foot of loosely spread meat.

The first experiment was an attempt to dry approximately 100 lb. of trimmed meat (pressure cooked, method three) as a single charge. The dry bulb temperature during the first two hours of drying was 77° C. (170° F.)

and during the last two hours 51° C. (124° F.). The relative humidity during the first two hours dropped from 60 to 37% and during the last two hours from 64 to 46%.

This experiment was unsuccessful (Tables VIII and IX) as the moisture content of the final product was too high. Also, the time involved in mincing and loading the trays with this quantity of meat was of sufficient length to allow the meat to cool and develop off-odours.

TABLE VIII

CHANGES IN WEIGHT AND AMOUNT OF MOISTURE IN MEAT LOAD PER TRAY DURING DRYING

Drying time	Change in weight of meat load (lb.)		Apparent percentage of total moisture removed calculated from loss of weight	
	Experiment one	Experiment two	Experiment one	Experiment two
Initially	3.70	3.70	—	—
One hour	2.73	2.52	43.8	64.8
Two hours	1.83	2.10	84.6	88.0
Three hours	1.65	1.90	92.8	99.0
Four hours	1.55	1.76	97.2	106.6
	Actual moisture loss		92.0	96.1

TABLE IX

QUALITY OF INITIAL AND DRIED PORK

Characteristic	Experiment one		Experiment two		
				Dried	
	Initial	Dried	Initial	Mean	Standard deviation
Moisture content (%)	59.7	10.7	49.2	3.8	0.5
Fat content (%, *D.M.B.*)				31.6	5.4
Organoleptic rating			8.6	8.5	0.2
Peroxide oxygen value	0	0	0	0	
Thiamin retained (%)[1]		98.4		91.0	
Thiamin content (γ/gm. *D.M.B.*)				30.2	9.5

[1] *As per cent of that present in cooked, minced meat.*

In the second experiment approximately 100 lb. of meat (open-pot cooked) was dried in 25 lb. lots. The lots were introduced into the drier at hour intervals, one column of trays being loaded at a time. To reduce the temperature of the air passing over the partially dried charge the fresh lot was introduced between the partially dried meat and the hot air delivery. The temperature conditions in the initial stages of drying during the second

experiment were: dry bulb, 81° C. (178° F.); wet bulb, 43° C. (110° F.). During the period when no more meat charges were introduced, a dry bulb temperature of 71° C. (160° F.) and a wet bulb temperature of 37° C. (98° F.) were used. The reduced temperature was selected as equivalent to the reduction in temperature caused by the introduction of fresh meat and difference in position of the charges in the tunnel. The average loss in temperature across a column of trays during the first hour of drying was 6° C. (10° F.); during the second hour, 2° C. (4° F.); and during the third and fourth hours no loss could be detected by the methods used. The loss in temperature occurring in the tunnel was 0.2° C. (0.3° F.) per foot of tunnel length.

Table VIII shows the average change in weight of a tray of meat during drying by each method and the apparent loss in moisture, expressed as a percentage of the moisture present in the cooked meat. The greater actual weight loss in the meat dried in the first experiment is a result of the slightly higher moisture content of pressure cooked meat. The percentage moisture loss calculated on weight changes during drying is greater than the actual decrease determined by moisture analyses. This difference had been observed in earlier work and was believed to be due to the loss during drying of volatile components other than water.

Table IX records the results of analyses of the initial and final product. The product obtained in the second experiment was of excellent quality, although 27% of the thiamin was destroyed during the cooking process. This was greater than the loss (approximately 13%) observed in previous experiments.

These results indicate that drying conditions found satisfactory for the small tunnel drier could be applied when a larger drier was used providing mincing is followed by rapid introduction of meat into the drier.

In general, pork can be successfully tunnel dried to yield a product that when reconstituted is as palatable as the initial material. However, investigation of drying methods is continuing.

Acknowledgments

The author wishes to express thanks to Dr. A. H. Woodcock, Messrs. T. A. Steeves, and E. A. Chadderton for their assistance in constructing driers and to Messrs. R. T. Legault and K. McDonald for their assistance in operating the driers.

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PARASITES OF TROUT IN ALGONQUIN PROVINCIAL PARK, ONTARIO[1]

By D. A. MacLulich[2]

Abstract

The parasitism of trout in Algonquin Park, Ont., was studied during the spring and summer of 1939 to determine the distribution and abundance of parasites in the several species of trout. The sampling included 34 lakes from five different river drainages.

A list of the parasites follows with the hosts indicated by the letters, *C* for *Cristivomer namaycush* Wahlbaum, *S* for *Salvelinus fontinalis* Linnaeus, and *F* for *Salmo fario* Linnaeus. Protozoa (cysts in kidneys),—*CSF*; trematodes: *Crepidostomum farionis*,—*CS*, *Azygia angusticauda*,—*C*, *Clinostomum complanatum*,—*S*, *Neascus* sp. (larvae),—*S*; cestodes: *Diphyllobothrium* sp. (larvae),—*C*, *Eubothrium salvelini*,—*CS*, *Proteocephalus ambloplitis* (larvae),—*CS*, *Proteocephalus parallacticus*,—*CSF*, *Proteocephalus pusillus*,—*C*; nematodes: *Cystidicola stigmatura*,—*CS*, *Philonema* sp.,—*C*, unidentified larval nematodes,—*CS*, acanthocephala: *Leptorhynchoides thecatus*,—*C*; copepoda: *Salmincola edwardsii*,—*S*, *Salmincola siscowet*,—*C*.

Two of the tapeworms, the two copepods, and the protozoan kidney cysts were generally distributed. The other parasites showed local differences in abundance. Frequency distribution studies of several of the parasite populations indicated that the parasites are not distributed randomly to the hosts.

Introduction

The parasitism of trout in Algonquin Park, Ont., was studied during the spring and summer of 1939. The purposes of the investigation were to determine the distribution and abundance of parasites in the several species of trout. This information was desirable for fish cultural work in the Park waters. Statistical studies of parasite populations from an ecological standpoint are scarce and attention was directed to frequency distributions of several of the parasite populations. The study of the structure of parasite populations is a field of ecology that will repay further investigation and might yield important methods of management.

The data, showing in detail the lakes sampled and the abundance of each parasite in the trout, are deposited with the Royal Ontario Museum of Zoology. Frequency distribution tables of microsporidian, *Diphyllobothrium*, *Eubothrium*, *Proteocephalus*, and copepod populations are available in the same place.

Material

A full examination was made of 177 lake trout (*Cristivomer namaycush* Wahlbaum), 18 speckled trout (*Salvelinus fontinalis* Linnaeus), and one brown trout (*Salmo fario* Linnaeus). In addition, 423 lake and 94 speckled trout were partially examined for certain parasites such as copepods, cysts of

[1] *Manuscript received in original form May 12, 1942, and as revised, October 14, 1943. Contribution from the Ontario Fisheries Research Laboratory, Department of Zoology, University of Toronto, Toronto, Ont.*

[2] *At the time, Ranger on the Staff of Algonquin Provincial Park, Ont.*

Diphyllobothrium, and microsporidians. The sampling included 34 lakes from five different river drainages. Further field work would probably disclose additional species of parasites.

Methods

The fish were largely obtained from anglers through the Creel census organization of the Ontario Fisheries Research Laboratory; the viscera were thereby available for examination, the flesh being retained by the anglers. Some trout were caught in nets or by trolling. Before the ice left the lakes fishing was done with lines left set with minnows for bait.

The intestinal parasites were collected by shaking the slit-open intestine in a quart sealer with a 0.7% solution of sodium bicarbonate, the sediment was allowed to settle, and the supernatant was poured off. Following several such washings the sediment was poured into a flat black dish. Few or no parasites were lost in the supernatant. The pieces of intestine were removed from the mixture when it was first shaken up and before it was allowed to settle. Any parasites adhering to the intestine were picked off.

In the black dish, 8 in. square, the trematodes, nematodes, and acanthocephala, all of which were scarce, were removed and their numbers estimated before the usually numerous cestodes that remained were counted. If the cestodes numbered over about 400, a wire frame was put in the dish marking out quadrants; the total number of cestodes was estimated from the number counted in one quadrant, the worms being approximately evenly distributed in the dish.

Cestodes and trematodes were fixed in hot Bouin's fluid, or occasionally in 10% formalin, the former giving the better results. Nematodes were fixed in hot 70% alcohol, and acanthocephala, after their beaks were extruded in lake water, were usually fixed in Bouin's fluid. Parasitic copepods were killed in cold 75% alcohol. All parasites, from which the Bouin's fluid was washed out in several changes of 50% alcohol, were kept in 75% alcohol.

Cestodes and acanthocephala were stained in Delafield's haematoxylin with differentiation in acid alcohol and the trematodes were stained in alum carmine. Nematodes, some acanthocephala, and the copepods were examined unstained, the two former in glycerine or lactic acid. Several cestodes were sectioned to elucidate characters required for identification. Many immature cestodes were identifiable to genus only and have been classified in the table with the species of adult tapeworms.

Annotated List

Protozoa

These microsporidian parasites, forming white cysts in the kidneys, were abundant in both lake and speckled trout from all lakes that were adequately sampled.

There were, however, differences in abundance. The lake trout in Redrock Lake had an average of 1.6 cysts each, in Opeongo 2.7, in Louisa 4.9, and in Butt Lake 8.1, and the speckled trout in Redrock Lake had an average of 3.1

cysts each. The Chi square test of goodness of fit applied to these series demonstrated that the apparent differences between them are all statistically valid. That is, the abundance of these cysts was different in four lakes, and within one lake, speckled trout and lake trout had different numbers of cysts. The reasons for such differences in population are not known.

The cysts were restricted to a short zone in the kidneys about opposite the anterior end of the dorsal fin. Once only was a cyst found further back in the kidney.

Trematoda

Crepidostomum farionis (O. F. Müller, 1784)

This trematode occurred in small numbers in the intestines of a few trout, both lake and speckled, from Happyisle and Redrock Lakes. An unusual occurrence was the presence of two flukes, *Crepidostomum*, in the gall bladder of a speckled trout from Redrock Lake. These flukes were identified by Mr. Allen McIntosh of the Bureau of Animal Industry, Washington, D.C., as *C. farionis*, and it is of interest to note that *C. cooperi* has been recorded from speckled trout in Lake Commandant, Que. (5).

Clinostomum complanatum (Rudolphi, 1814)

One specimen was present in the intestine of a speckled trout from Redrock Lake, probably *en passant* from a perch eaten by the trout.

Azygia angusticauda (Stafford, 1904)

A lake trout from Whitefish Lake had two specimens in its intestine.

Black Spot

One or two small black hard cysts were found in the pectoral fins of three speckled trout out of the 22 examined from Proulx Lake and in eight out of 18 speckled trout from Redrock Lake. None were found in the lake trout. The cysts contain a larval fluke, probably *Apophallus*, but the specimens have not yet been identified.

Neascus sp.

The minute black cysts of this larval parasite of perch were commonly liberated into the intestine of trout in the course of digestion of perch, but they passed through without opening, and are not to be considered intestinal parasites of trout.

Cestoda

Diphyllobothrium sp., possibly *cordiceps* (Leidy, 1871)

Plerocercoids of the genus *Diphyllobothrium* occurred in lake trout, but not in the speckled trout examined, in cysts in the wall of the stomach and adjacent tissues, tending to concentrate in the lesser curvature.

The infection was found abundantly in the following lakes: Big Crooked, Canisbay, Head, Louisa, Source, McKaskill, Butt, and Redrock. The degree of infestation for Louisa Lake averaged 28 plerocercoids per fish, whereas

the average in Butt Lake was only 15, and the difference was statistically significant. Infection was definitely scarce in the following lakes: Smoke, Opeongo, Big Trout, Cache, and Hogan. In Lake Opeongo the plerocercoids were entirely absent from all 89 lake trout examined.

Dr. E. Kuitunen-Ekbaum (2) reported the absence of *Diphyllobothrium* in 18 lake trout from Lake Opeongo in 1937, which is the same condition encountered in the present survey two years later. The great differences in abundance in various lakes are surprising in view of the probability that the parasite matures in fish-eating birds, such as gulls. It may be significant that trout are largely plankton feeders in the lakes in which *Diphyllobothrium* was abundant, as a plankton organism serves as host for the first stage larva.

The two infected lake trout from McKaskill Lake were caught under winter conditions before the ice left the lake and the *Diphyllobothrium* plerocercoids were all dead and disintegrating. This suggests that the infection is lost during the winter and picked up afresh in the spring; however the results from two fish only may be misleading. It happened that heavily infected lakes were not sampled in the spring, so that acquisition of the parasites was not traced, in fact they were not found alive until June. The numbers of cysts observed from June to September showed no significant change; for instance, in Louisa Lake the averages for July, August, and September were 24, 28, and 27.

The plerocercoid stages of several species of *Diphyllobothrium* are apparently indistinguishable morphologically and, as no life history studies were done, the form in Algonquin Park has not been positively identified. It is possibly *D. cordiceps* (Leidy, 1871), which has been reported in *Salmo salar sebago* and found to reach maturity in gulls and pelicans (4, 10, and 13).

That these *Diphyllobothrium* larvae are not *D. latum* (L., 1735) the broad tapeworm of man, is suggested by the fact that the Algonquin forms are encysted in the viscera and not in the flesh while *D. latum* occurs more usually free in the muscles of the host fish (12). Furthermore the experiments by Kuitunen-Ekbaum (2) and those of Woodbury (13) (reported by Magath (8)) suggest that *D. cordiceps* does not develop in man, cat, or dog.

Eubothrium salvelini (Schrank, 1790)

This was the common large tapeworm, occurring in 85% of the lake trout and in 66% of the speckled trout. *Eubothrium* was not found in either of the two fish from Smoke Lake, nor was it found in the seven Dickson Lake fish that were taken in winter. It was present in all other lakes examined. The percentage incidence, average numbers per infected fish, and the frequency distribution in Lake Opeongo are available at the Royal Ontario Museum of Zoology.

Of the 17 lake and speckled trout taken before the ice left the lakes 11 had no tapeworms, five had a few mature *Eubothrium*, and the last fish taken just before the break-up of the ice had mature and immature worms of both this species and *Proteocephalus*. The lakes sampled in late winter were Opeongo,

Proulx, Dickson, and McKaskill. The average numbers of mature *Eubothrium* in lake trout from Lake Opeongo for May, June, and July, were 2, 13, and 14. The numbers of immatures for the same months were 21, 38, and 37.

The Algonquin Park material showed a wide variation in taxonomic characters, which is described elsewhere (7).

Proteocephalus parallacticus MacLulich, 1943

This small tapeworm was abundant in the intestines of the majority of the lake trout from all river drainages. The one significant exception was Redrock Lake from which four lake trout and five speckled trout were examined without finding any *Proteocephalus*. The two speckled trout from Casey Lake also lacked this species. Other speckled trout and a brown trout carried this tapeworm.

Proteocephalus was not in the fish taken in winter except in the last fish taken as the ice began to break up. The average numbers of mature worms in lake trout in Lake Opeongo for May, June, and July were: 16, 91, and 143; the numbers of immatures were: 173, 260, and 459. The frequency distribution in Lake Opeongo is on file at the Royal Ontario Museum of Zoology.

As the combination of characters exhibited by the Algonquin Park material was not described in the literature this was made a new species (6).

Proteocephalus pusillus (Ward, 1908)

Dr. R. V. Bangham found this species in lake trout from Canisbay Lake.

Proteocephalus ambloplitis (Leidy, 1887)

This parasite was probably introduced to this area with the small-mouthed black bass (*Micropterus dolomiu*) that were planted in the southern part of the Park as the definitive hosts are known to be various species of bass (3). The "larvae" or immature worms are commonly found in a number of fish in which they are unable to reach maturity (11). Since trout frequent deeper water than bass during much of the year it is not surprising that the larvae of this bass parasite are of rare occurrence in trout. However a speckled trout from Lake Opeongo had one immature in the stomach, 12 in the caecal part of the intestine, and none in the lower part of the intestine. The food in the stomach, namely, a short-tailed shrew, *Blarina brevicauda*, and a young perch, *Perca flavescens*, suggested that this fish had been feeding near shore where it would be more likely to pick up *P. ambloplitis*. The largest specimen was 4 mm. long. Immature specimens of *P. ambloplitis* were found in the stomach or intestine of three lake trout from Lake Opeongo.

Nematoda

Cystidicola stigmatura (Leidy, 1886)

These roundworms occurred in the air bladders of lake trout and speckled trout in Hogan Lake and Wilkes (formerly Manitou) Lake. The infestations were severe but in most cases appeared to cause no gross damage. Hemorrhage from the bladder wall occurred in two out of the 25 infected trout,

but it is not known whether the worms were responsible for this condition or not. One immature specimen was found in the intestine of a lake trout from Big Trout Lake.

Philonema sp.

These large filarioid worms occurred infrequently free in the body cavity of lake trout from Lake Opeongo. They were not found in fish from any other water.

Large irregular cysts containing dead worms or brown remains of them were apparently due to a foreign-body reaction of the host, walling off the worm after its death. Of 73 trout from Lake Opeongo four had living worms, two of these had encysted dead worms, and 15 others had dead cysts alone. Two fish, not used in the above figures since they were chosen for examination because they had severe infections, had 19 living worms in one and seven living and 14 dead worms in the other fish.

Larval Nematodes not Identified

Delicate larval roundworms were encysted in the viscera, most of them in the liver, of both lake and speckled trout. Other immature roundworms occurred free in the intestines.

Acanthocephala

Leptorhynchoides thecatus (Linton, 1891)

Thorny-headed worms were restricted to lake trout from Lake Opeongo and were not common there.

Parasitic Copepods

Salmincola siscowet (Smith, 1874)

Small numbers of these external parasites occurred occasionally on the skin and fins of lake trout. They were particularly abundant in Louisa and Butt Lakes, and their frequency distributions in those two lakes showed no significant difference. The average number of copepods per fish in those lakes was 1.1.

The type of frequency distribution of a parasite population must be influenced by, and be the result of, the life history of the parasite and the life and ecology of the hosts and environment. For instance, if the parasites were *randomly* distributed to the fish as a result of the ecological situation, the frequency of occurrence of various numbers of parasites per host would follow a Poisson probability series. The facts are, see Table I, Columns 3 and 4, that the copepod numbers show too many high values and are not statistically of the Poisson type. This is true for all the parasites studied in this investigation (microsporidians, *Diphyllobothrium*, *Eubothrium*, *Proteocephalus*, and copepods) with the exception of the microsporidians that occurred in lake trout in Redrock Lake, which is probably a fortuitous circumstance.

In an attempt to throw some light on the factors controlling copepod distribution various mathematical distributions are presented in Table I with

their "Goodness of Fit" indicated for each. It is evident that only the last two distributions fit the facts.

TABLE I

PARASITIC COPEPODS ON LAKE TROUT IN LOUISA AND BUTT LAKES. COMPARISON OF ACTUAL DISTRIBUTION WITH VARIOUS MATHEMATICAL DISTRIBUTIONS*

Number of parasites on a fish	Frequency, numbers of fish		Poisson distribution	"Original" distribution	Neyman's contagious distribution
	Observed data	Smoothed data			
0	68	68	44.5	68.9	72.0
1	29	29	48.5	24.9	21.0
2	14	15	26.4	18.2	17.0
3	11	9	9.5	10.4	10.4
4	2	4	2.6	5.4	5.7
5	4	3	0.6	2.7	3.0
6	2	2	0.1	0.8	1.5
7	2	2	0.0	0.5	1.4
Total number of fish	132	132	132.2	131.9	132.0
Averages, copepods per fish			1.09	1.09	1.09
Probability of a worse fit			0.04	0.43	0.38
Goodness of fit			Nil	Good	Good

** Note that a probability of 0.50 means that the hypothesis fits perfectly and that a probability of 0.04 means that only four times out of every 100 sets of data could a worse fit be expected, i.e. it is strongly indicated that such a hypothesis fails to account for the facts. The probability is derived from the table of χ^2 (1).*

The second last is an original distribution involving two ideas or symbols, one for the average number of swarms of copepods met by a fish, and a second symbol for the average number of parasites picked up by a fish in passing through a swarm. Two assumptions are involved: one, the fish meet the swarms purely by chance, and, two, the numbers of parasites picked up in passing through swarms form a random distribution. Both assumptions, therefore, are described by Poisson series. The net result is a distribution that allows for the swarming of the nauplii and the two above assumptions of pure chance. The excellent "Goodness of Fit" is strong evidence that the above hypotheses are a first approximation to the truth. The numerical values are as follows: mean number of swarms met by a fish per season equals 0.98; and mean number of copepods picked up in passing through one swarm equals 1.11.

The third, "Neyman's Contagious Distribution of Type *A* with two Parameters" (9), is based on the idea of grouping or "contagiousness" i.e. if there is any infestation at all several parasites are apt to be present. It is plain that a population built up on the principles described in the previous paragraph will display a degree of this quality of "contagiousness".

Salmincola edwardsii (Olsson 1869)

This species was carried in small numbers by speckled trout. In one case only was the infestation severe; this was in a speckled trout from Dickson Lake with 21 copepods on the gills and one on the adipose fin on March 20.

Acknowledgments

Acknowledgments are due to the Superintendent, Mr. F. A. MacDougall, for making the investigation possible by loaning the writer (who was on the ranger staff of the Park) to the Ontario Fisheries Research Laboratory and providing a canoe and other facilities. The Director of the above laboratory, Professor W. J. K. Harkness, and other members of the staff, aided materially with laboratory space, supplies, and co-operation in many ways. Much of the laboratory work was done in the Ontario Research Foundation, Toronto, and grateful acknowledgment is made to the Director of the Foundation, Dr. H. B. Speakman, and to Dr. S. Hadwen, the Director of Pathology and Bacteriology, and his assistant, Dr. A. M. Fallis. The Director of the Royal Ontario Museum of Zoology, Professor J. R. Dymond, gave work space in the Museum for part of the time.

Aid of various sorts from the following persons is also acknowledged: Dr. R. V. Bangham of the College of Wooster, Wooster, Ohio, Mr. J. S. Hart of the Ontario Fisheries Research Laboratory, and Dr. E. W. Price, Bureau of Animal Industry, Washington, D.C.

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STUDIES ON TRICHINOSIS

IV. HUMAN INCIDENCE IN MONTREAL[1]

By T. W. M. Cameron[2]

Abstract

On the basis of 539 unselected samples examined, the incidence of human trichinosis in the Montreal district was found to be 1.5%.

From December, 1940, until February, 1943, samples of diaphragm were collected at the morgue of the Royal Victoria Hospital, Montreal, Que., and from June, 1941, until February, 1943, at the Montreal General Hospital as well. Except that children under one year old were excluded on the hypothesis that they could only have been exposed to infection prenatally, no selection was made. All samples were taken from the diaphragm and conveyed in waterproof cardboard containers to this Institute where they were examined both by compression and pepsin digestion techniques for the presence of encysted trichina larvae.

Three hundred and one diaphragms were examined from the Royal Victoria Hospital and 238 from the Montreal General Hospital—a total of 539 in all. Of these, eight, or 1.5%, were positive (five from the Royal Victoria Hospital and three from the Montreal General Hospital). All the infections were light, the heaviest being 19.5 larvae per gram of diaphragm. In all samples the larvae were alive; no dead larvae or trichina-like objects were detected by examination with the compressorium. These results agree with those published by E. Kuitunen-Ekbaum at Toronto (2) while the Montreal survey was in progress. She examined 420 cases in all, but 77 were under one year old. There were accordingly 343 cases comparable with the Montreal series. Of these, six were positive, although in three of them, the cysts were calcified. This gives an incidence of 1.75%. The infections were very light ones.

It seems legitimate to conclude, therefore, that the incidence of human trichinosis in Eastern Canada is probably about 1.5 to 1.75%. It must be recalled, however, that this is a helminthic infection, which is not contagious, and that incidence figures do not have the same significance as in bacterial diseases. A single infected pig may cause a sharp local outbreak with serious disease, even although the incidence for the country as a whole is low. A more pertinent figure is the incidence in hogs, although even then the figures require interpretation in the light of the feeding habits of the people. The light infections in the Montreal series suggest that such infections as do occur, do so as the result of eating undercooked, rather than uncooked pork. Nevertheless, outbreaks due to uncooked pork have been recorded in Montreal.

[1] *Manuscript received September 30, 1943.*

Contribution from the Institute of Parasitology, McGill University, Macdonald College, Que., with financial assistance from the National Research Council of Canada.

[2] *Professor, McGill University; and Director, Institute of Parasitology, Macdonald College, Que., Canada.*

In Eastern Canada, the general incidence of hog trichinosis is 0.57% (1). In the United States, the hog incidence is higher, 2.5%, and the human incidence much higher, 16.7% (3). It will be noted, however, that the incidence of hog to human trichinosis in Canada is about 1 : 3, while in the United States, the ratio is 1 : 6.68; that is, one hog infects about twice as many people in the United States as a hog in Canada.

The larger amount of hog trichinosis in the United States is due to some hogs being fed uncooked garbage; the incidence in those fed no garbage, or cooked garbage, is comparable with the Canadian figure. As the exact proportions of these classes is unknown, the figures for the United States are not absolutely accurate and the incidence in hogs may be as low as 1.5%. This merely increases the disproportion. This can be explained only by assuming that a higher proportion of persons in the United States eat pork undercooked or uncooked than in Eastern Canada.

The elimination of feeding uncooked garbage might be expected to reduce human infection in the United States to between 3 and 4%, assuming no change in the feeding habits of the people. Obviously, therefore, education on the dangers of raw or undercooked pork would be still essential.

It also follows from these comparative figures that the elimination of uncooked garbage from the hogs' diet will reduce the incidence and especially the severity of infection, but it will not eliminate it. This may be due partly to evasion of the law or it may be due to some cause still unknown.

The collection and digestion of the specimens was carried out by Sgt. Douglas Conlon, R.C.A.F., and it was made possible through the co-operation of Professors G. Lyman Duff, L. J. Rhea, and Theo. R. Waugh.

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CANADIAN JOURNAL OF RESEARCH

VOLUME 21
1943

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CANADA

Published by the
NATIONAL
RESEARCH COUNCIL
of CANADA

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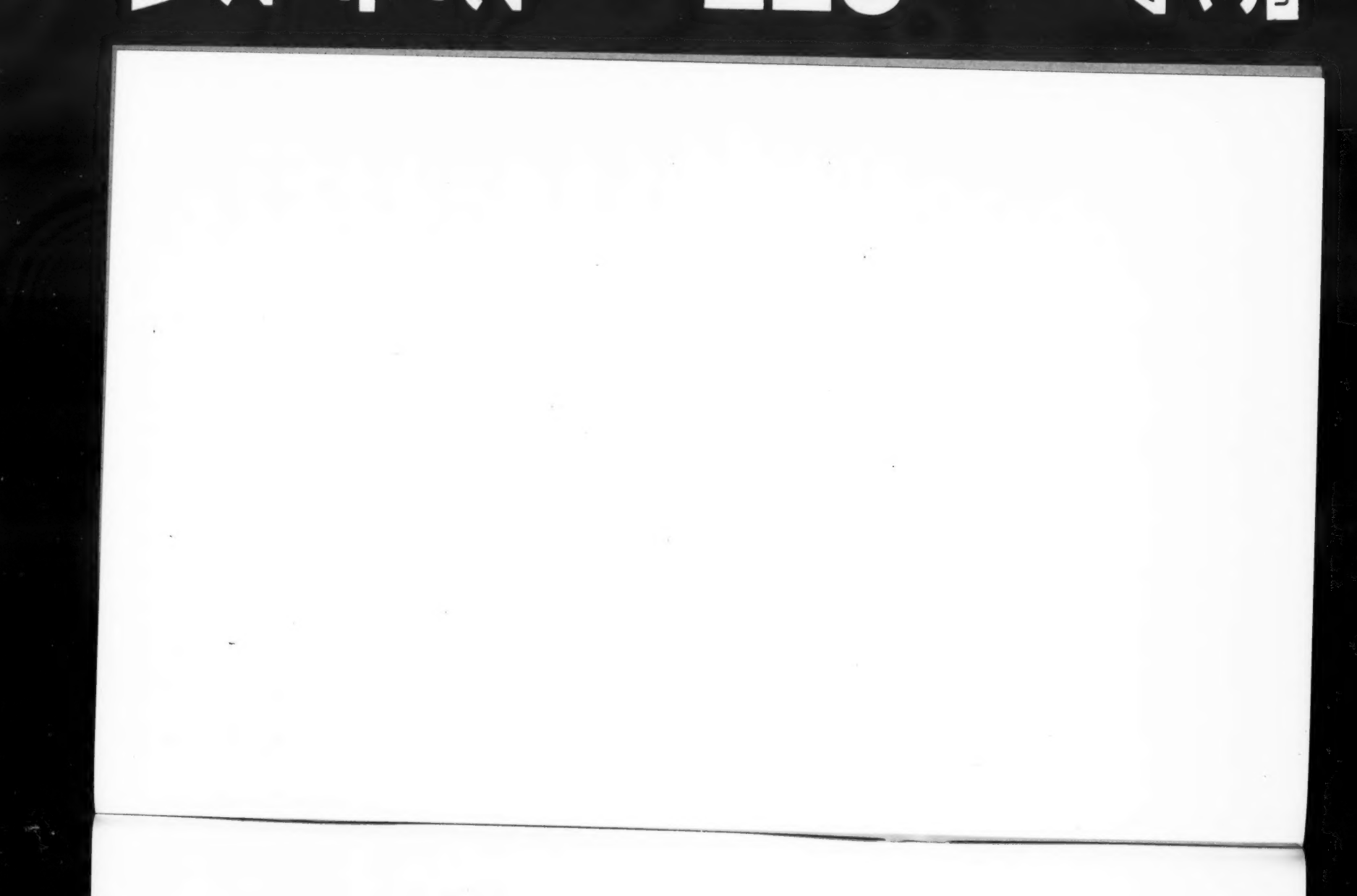

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